United States Department of Agriculture

Animal and Plant Health Inspection Service

Plant Protection and Quarantine

June 1997

New Pest Response Guidelines

Pink Hibiscus Mealybug
Maconellicoccus hirsutus

This PPQ Action Plan or New Pest Response Guideline has not been updated since its publication date. The actions or guidelines recommended may not be appropriate now, new survey tools may be available, and chemical pesticides named may no longer be registered. This documents is posted until updated versions can be drafted and as such are only guidelines that represent the state of knowledge at the time they were written. Please consult PPQ and/or your State Plant Regulatory Official prior to implementing any recommendations listed herein.

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PURPOSE AND DISCLAIMER

Purpose

These New Pest Response Guidelines provide information concerning actions for mitigating the impact of any of the pink hibiscus mealybug (Family Pseudococcidae, Order Hompotera).

These Guidelines are to be used as an aid for States when developing State action plans. The procedures described in these New Pest Response Guidelines were developed by Plant Protection and Quarantine (PPQ), Plant Protection Laboratories (PPL) staff through discussion, consultation, or agreement with other Animal and Plant Health Inspection Service (APHIS) staff, the Agricultural Research Service (ARS), and university advisors.

Disclaimer

This document is not intended to be complete and exhaustive. The information given herein was taken from some of the available literature and synthesized into a specialized document intended to assist further work, as stated above. Some key articles were not available at the time this was written, nor have all pertinent specialists and other members of the research community been consulted for their advice.

GENERAL INFORMATION

Action Statement

The information contained in this document is intended for use as guidance in designing a program to detect and respond to an infestation of the pink hibiscus mealybug (PHM), *Maconellicoccus hirsutus*, Family Pseudococcidae (Homoptera). These New Pest Response Guidelines provide information on implementing detection, control, containment, or eradication programs. Specific emergency program action must be based on information available at that time.

Initial Program Procedures

The following steps should serve to initiate program efforts and should be kept in mind throughout the beginning stages.

Step 1—Identification and Detection:

It will be most important to determine the identification and detection procedures that will be used throughout the program. Options which may be used are given in Identification Procedures and Addenda 4 and 7 of this document.

Step 2—Determining the Scope of the Problem:

It will be necessary to determine the extent of the infestation and the difficulties faced by program managers during a good survey and to identify the biological (Addendum 7, Life History) and practical realities in advance of any active program to control, suppress, or eradicate PHM.

Step 3—The Response: No Action to Eradication:

The effectiveness of the various control options will be considered, including regulatory action (Regulatory Procedures), available options for control or suppression of the target population, and destruction or treatment of the hosts (Control Procedures and Addendum 5). From this information, and in the light of available resources, a decision must be made to either take no action (a program is impractical), or to control, suppress or eradicate the target population, if possible (See V. B and C for Decision options).

Background and Information

The PHM is a small, white waxy textured insect with a soft body. The female is wingless, but the male is capable of flight. The intermediate life stages are eggs and three (female) or four (male) nymphal instars. Each female will lay from 150 to 650 eggs in an ovisac. This is usually laid on the host plant. Sometimes the ovisacs are present in great numbers and visible as a whitish waxy covering over the terminal parts or even main branch or trunk areas of the host. The female, the nymphal stages, and the male, if present, are very visible on the host, as well. All stages are reddish to pink in color, but covered in white mealy wax, with the body color usually showing through. For that reason, it is often called the pink mealybug.

The PHM appears to be native to Australia or Southern Asia, as based on its distribution and that of other members of the genus *Maconellicoccus*. It is the only species with a virtually world-wide distribution in tropical areas of the world from Australia through Southeast Asia, the Middle East, and central Africa. It has recently spread to Guam, Hawaii, and the Caribbean.

Background Information (continued)

In many countries, this pest seems to be chiefly restricted to *Hibiscus* and is not of concern, possibly because it is kept in check by natural enemies. In some areas of India and Egypt, however, it is a serious pest of some importance, especially where no natural controls are present. In these countries it does seem to have many hosts, but of these hosts, few are heavily attacked. When this mealybug turned up in Hawaii in 1984, it did not become a major pest problem, for natural enemies were apparently, fortuitously imported with it. In Grenada and other Caribbean islands where natural enemies were absent, it became a very serious problem, attacking many plants and disrupting the agricultural sector to a major extent.

Another species, *M. multipori*, restricted to Southern Asia, has turned up in interception records on various hosts and while not yet reported to cause any damage to the hosts, such damage cannot be ruled out if it is accidentally introduced to other areas (Williams, 1996).

Life Cycle Information of Vector

Development of *M. hirsutus* is temperature dependent. Egg, nymphal, and adult reproductive developmental rates are influenced by air temperatures. (In this situation, there is a minimum temperature threshold below which no measurable development takes place.) A developmental model that uses modified air temperature data can be used to predict the length of the entire life cycle. The temperatures for these developmental thresholds has not been determined for the PHM. In the absence of this data for program purposes, it is reasonable to use information taken from a related mealybug, the Cassava mealybug, *Phenacoccus manihoti*, to serve as a model. This species also has a tropical distribution (Iheagwan & Eluwa, 1983).

A number of degrees accumulated above the developmental threshold for a life stage is called day degrees. One day degree (DD) is 1 day with the average temperature 1° greater than the threshold for development.

Caution should be exercised in the use of any models for DD. For example, the thermal limit for egg hatch of the unrelated Douglas-Fir tussock moth, *Orgyia pseudotsugata*, may be reached in thinned stands of trees **7-10 days earlier** than eggs in unthinned sites with less solar warmth (Wickman & Torgersen, 1987). Obviously, exposure to the sun's warmth made this difference. Since PHM can also thin the canopy if in high numbers, this type of rapid development can be anticipated. It can also be anticipated whenever a host is exposed to high levels of solar radiation, such as a host growing by itself in a field or for display purposes.

For the model depicted in the Table 1—1, 501.62 DD(260.9 DD in Celsius) must be accumulated before one life cycle has been completed for the Cassava mealybug (Iheagwam & Eluwa, 1983).

Life Cycle Information of Vector (continued)

Table 1-1: **Day degree calculations**

Formula:

Minimum Daily	Maximum Daily	Total	Average Daily	Thresholds	Day Degrees
Temp °F +	Temp ° =	Temp °F # of DD	= Temp °F / 2	= Temp °F	-

Example: (Air Model with 50.0 and 89.96 °F thresholds)

Minimum Daily	Maximum Daily	Total	Average Daily	Thresholds	Day Degrees
75 °F +	86 °F =	161 °F / 2	= 86.5 °F -	68 °F =	12.5 DD

Table 1—2 **The full Threshold and DD data for *Phenacoccus manihoti***

	Threshold	Day Degrees
Egg	14.0 °C = 57.2 °F	131.4 in C = 268.5 in F
1st nymphal stage	20.0 °C = 68.0 °F	34.1 in C = 93.4 in F
2nd nymphal stage	19.0 °C = 66.2 °F	33.0 in C = 91.4 in F
3rd nymphal stage	19.5 °C = 67.1 °F	32.5 in C = 90.5 in F
Immature adult	17.0 °C = 62.6 °F	58.5 in C = 137.3 in F
Egg to Adult TOTALS	20.0 °C = 68.0 °F	260.9 in C = 665.12 in F

Program actions are governed in part by pest life cycle data. Control or eradication treatments, length of survey activities, and regulatory functions are affected primarily by the length of time it takes for the pest to complete its life cycle.

Life Cycle Information of Vector (continued)

Because the DD data for PHM has not been determined, an alternative way to determine life cycles (other than direct observation) would be to take the life cycle under fluctuating tropical conditions, which is about 30-50 days in St. Kitts, (at 25°C=77°F, PHM has a 48.3 day life cycle) and add about a month (30 days) to that for program purposes. This rough rule-of-thumb must be made to cover all possible contiguencies which would tend to lengthen the life cycle and thus affect the length of program operations.

Temperature data are available from the National Oceanic and Atmospheric Administration, the U.S. Department of Commerce, private, State, university, or industry sources, or from remote site weathering monitoring station run by any of the above. Unforseen delays in completion of the life cycle must be anticipated.

IDENTIFICATION PROCEDURES

Correct and proper identification is the key to determining whether a program will be attempted, and if so, the extent, direction, and magnitude of the program. It will also help determine program changes and program failures. The decision to discontinue a program will very likely be the result of a determination that program efforts are not succeeding, based on identifications of perceived spread or finds.

Identification Characters

Some pre-identification and screening can be done by field personnel assigned to a program. In general, a description of the PHM, with pictures and drawings, should be prepared for the program. This should include distinguishing features which separate the PHM from any local species that resemble it.

Notes: For taxonomic purposes, the genus *Maconellicoccus* may be separated from *Paracoccus*, the closest known relatives, by the following features in the female adult: a pseudo-articulation in the 9th (terminal) antennal joint, the anterior leg with unequal tarsal digitules, and with small oral collar tubular ducts present on both the dorsal and ventral sides of the body (Ezzat, 1958). D. Odermatt, taxonomist with USDA, ARS, in a personal communication to APHIS, PPD, in 1966 added two other characters for the genus, including up to six pairs of cerarii and with ventral anal lobe bars present.

Properly cleared and mounted adult females of *M. hirsutus* may also be separated by microscope from adult females of the other seven species in the genus by possession of a circulus (an adhesive ring-like structure in the middle of the abdomen between the 5th and 6th segments), four to seven pairs of cerarii (clusters of pores and setae on the sides of the body), antennae no longer than 480 μm, oral rim tubular ducts (a mushroom shaped duct in the body surface with a terminal filament) of one size only and of these, oral collar tubular ducts in rows across the middle of the dorsal segments. Of these features, the possession of a circulus will separate *M. hirsutus* from the other most likely *Maconellicoccus* to be intercepted at ports, or to be accidently introduced, like *M. multipori*. (Williams, 1996)

General Description of *Maconellicoccus hirsutus*: (Green) (Hall, 1921)

This rather general description is modified for field use insofar as this is practical. There is a detailed description of the instars in Ghose, 1971. A chart for field use to help separate PHM from other common species is in the Biological Control of PHM Project Manual (Attavian, 1997).

Nymphal Instars—(Crawlers - 1st instar) Elongate and ovate, a delicate pink in color. Legs and six-jointed antennae well developed. No marginal appendages, but occasionally a little cottony secretion posteriorly. The anal lobes are more prominent than in the adult.

Identification Characters (continued)

Adult Female—Length 2-3.5 mm, width 0.9-2 mm. Reddish in color, sparsely covered with white flocculent (wool-like) wax with body color showing through. No lateral wax fringe filaments present, but two very short and rather indistinguishable wax-like posterior filaments are present at the rear end. There may be a little cottony secretion at the posterior extremity. Antennae nine-jointed, (last segment pseudo-jointed), with prominent stout hair on last three segments. Wings absent, body slightly elongate and ovate.

Male puparium—Somewhat elongated and formed of a very loose mass of fine white filaments. Length 1.1-1.5 mm, width 0.35-0.45 mm.

Male 4th Instar—(Pupa) Brownish in color, wing sheaths developed. Antennae directed backwards and held down close to the margin of the head and thorax. Length 1.25 mm, width 0.4 mm.

Adult Male—Pinkish in color, with eyes and ocelli black, the lower ocelli slightly larger. Wings present, iridescent. Caudal filaments present, white, rather stout and as long as the rest of the insect, each filament supported by two hairs half the length of the filament. Antenna 10 jointed, hairy, last three joints with a stout prominent hair at end of last three segments.

Female Ovisac—White, about twice as long as wide, rounded at ends and roughly semicircular in cross section. The outer shell is of matted fibers, and inside, numerous eggs are arranged in a loose network of fibers.

Egg—A very delicate pink, with a decidedly pink cap at one end. Surface apparently somewhat pitted or mottled with small cottony filaments from the ovisac generally attached. Length 0.35 mm, width 0.2 mm.

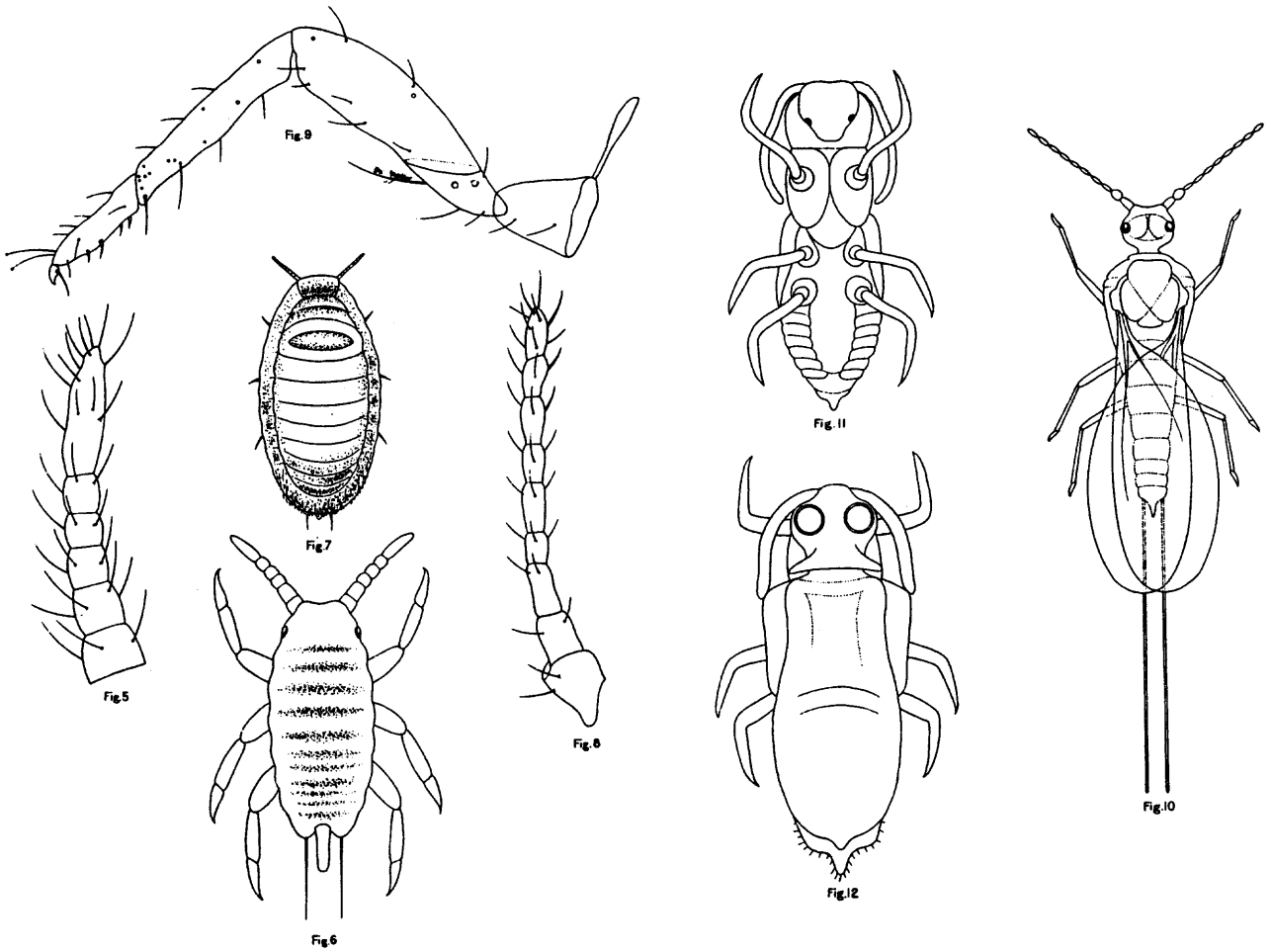


FIG. 5. Antenna of larva. (×500)
„ 6. The larva. (×150)
„ 7. Adult female. (×250)
„ 8. Antenna of adult female. (×250)
„ 9. Posterior leg of adult female showing group of minute glands on tibia. (×200)

FIG. 10. The male. (×70)
„ 11. Male pupa—ventral. (×65)
„ 12. Male pupa—dorsal. (×80)

(Drawings from Hall, 1921)

Collection of Specimens

As many specimens as possible of suspect mealybugs should be collected for screening or identification by the local identifier. Collecting a sufficient number of specimens should not be difficult since officers will most likely discover colonies of mealybugs and not individual specimens. A reasonable number of suspect specimens or colony on a host sample in a properly labeled and closed bag will be collected for screening/identification by the local designated identifier (Addendum 3).

Suspect life stages collected by hand should be killed by placing in 70 to 75 percent ethyl or isopropyl alcohol.

Currently, specimens will be collected as a result of visual survey. Until a synthetic pheromone is available or the decision is made to run traps with virgin females, pheromone trapping is not likely to be employed.

Collection of Specimens (continued)

Suspect males collected from pheromone traps should be handled carefully. The following procedures are recommended to ensure that specimens caught in sticky material can be accurately identified:

1. Ship entire card. Pin the card in a mailmaster type pinning box. Place it in a second shipping box and put padding between the two boxes.

or

2. Cut out a portion of the card surrounding the specimen. This will leave you with the specimen imbedded in sticky material on a small piece of cardboard. Put an insect pin (number two size) through the cardboard and pin the cardboard (with specimen attached) in a mailmaster type pinning box. You are treating the specimen as a pinned specimen and do not need to use alcohol or other liquids. To ship the pinning box for identification, place it inside a second shipping box and put padding between the two boxes.

or

3. Place sticky card in a clear plastic bag (lunch-sack or sandwich bag) and ship. Area can be examined under a microscope and specimens can be cut out.

Cardboard Band Trapping:

This technique is labor intensive and not likely to be employed, except under certain circumstances.

Material collected in corrugated cardboard band traps must be handled differently. All traps are collected and brought in by each trapper in individually sealed bags. Because this is live material, they are held in cold storage at 50°F (10°C) until they are to be examined. Mealybugs found under the band should also be removed from under the bark for examination as well.

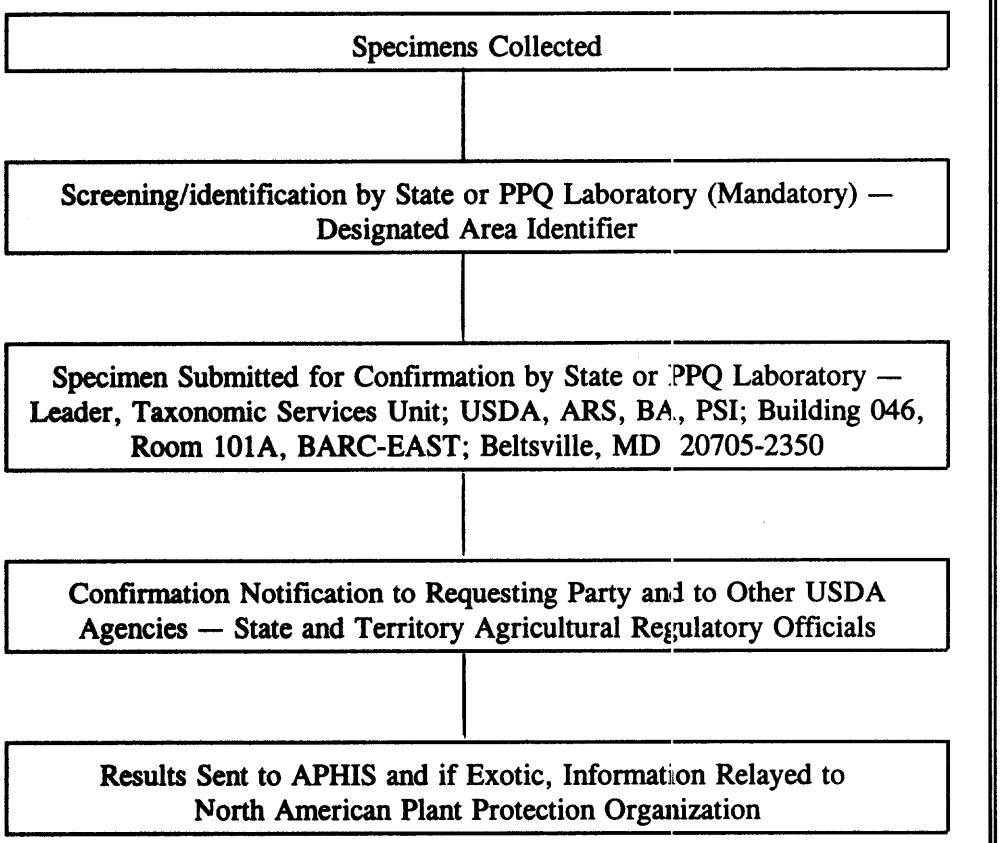
Immediately prior to examination, each band is to be submerged in tap water for a few minutes to facilitate the separation of the corrugated inner lining from the outer casing. The specimens are usually found between the two layers of paper. Adult females, ovisacs, and immature life stages will usually be found. The majority of the immatures will be developing males or parasitized mealybugs. A reasonable number of suspect specimens are to be collected for identification by means of a forceps or a vacuum-pump aspirator. (DeBach, 1949)

Collection os Specimens (continued)

Confirmation:

All suspect specimens should be forwarded for confirmation to the designated area identifier (1/) in the following chart. All specimens must be accompanied by PPQ Form 391 marked "Urgent" or similar State or local form. Telephone the identifier's office prior to shipping specimens to alert him/her of the shipment.

Information Flow for the Identification of Specimens



SURVEY PROCEDURES

The survey effort is to determine the extent and means by which the pest is spread. Conversely, it is also used to determine pest-free areas. Human and other natural means of dispersal must also be considered. Such pathway dispersal must be factored into an active survey if it is not adequately covered under Regulatory Procedures.

Detection Survey

Cross Transit Surveys are recommended for a rapid detection survey for the PHM. This type of survey will also be used in support of a delimiting survey.

The survey proposed here is biased towards the primary selected host(s) of concern and in areas where the PHM, if introduced, might be expected to be found first. A special survey may be warranted for certain downwind areas due to possible air dispersal of the mealybug. Surveys may otherwise be custom-designed, depending on circumstances and upon the advice of a Scientific Advisory Committee.

Visual survey procedures will probably be the most important means of finding the PHM, as given in Addendum 4, Technical Survey Information, and looking for symptoms on hosts as described in Addendum 7, Life History, under Biology.

There are three types of areas to cover in this survey:

- **High Risk Areas** — Major cities and towns where residents and visitors may be expected to travel to and from geographic areas where the mealybug already exists. Locations where known host plants are planted around hotels, airports, seaports, train and bus stations, and other transportation centers are especially important (Hall, 1921).

- **Downwind Areas** — Those areas where winds may reasonably be expected to carry the mealybug from areas where it already exists.

- **Host Areas** — These areas would include residential, nursery, and commercial properties (such as hotels), plus agricultural areas where known host plants, especially favored hosts, are grown. There should be a bias for residential properties if hosts are grown for food or as an ornamental in back yards (i.e., string beans, sorrel, hibiscus, citrus).

Delimiting Survey (continued)

When one or more mealybugs are collected in an area, a delimiting survey should be implemented immediately to determine the population distribution. Using the site of the detection as the epicenter (focal point), the survey should use the following methods to delimit the extent of the infestation.

Generally, the survey should rely on visual survey procedures as given in Addendum 4, Technical Survey Information. The survey will be maintained for at least three PHM generations after the last positive find if an eradication option is pursued.

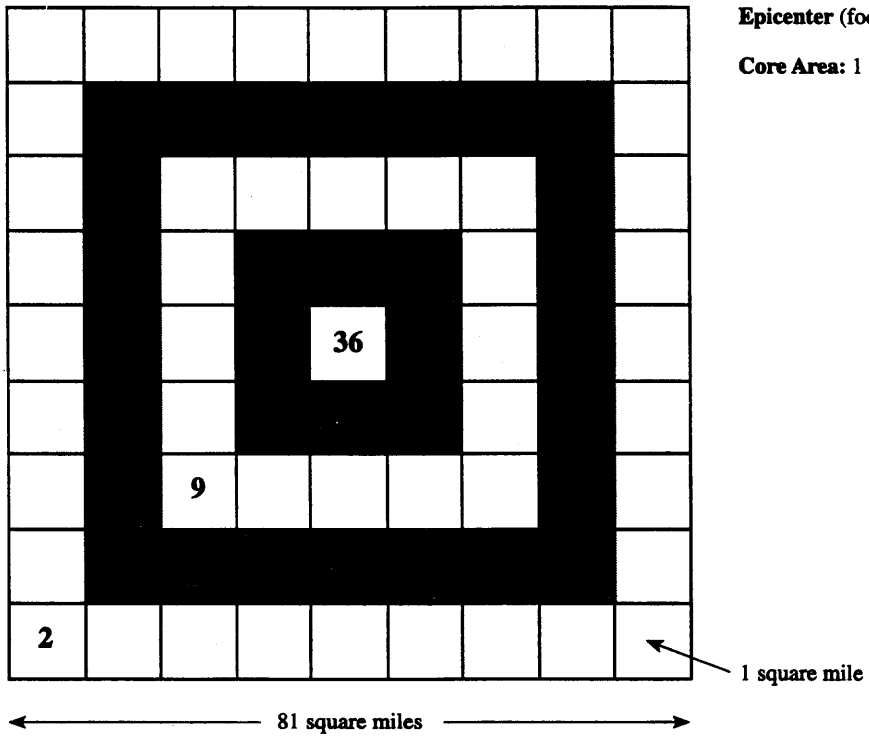
Trapping (sex pheromone, sticky traps, corrugated cardboard trunk bands, etc.) should not be undertaken unless the Scientific Advisory Committee recommends these procedures.

Cardboard traps should be set out around the trunk of host trees in a standard grid pattern within the core and buffer areas in a 36-18-9-5-2 per 81 square mile trapping array. The traps should be serviced and replaced monthly. In the event of an eradication program, traps will be maintained for the equivalent of at least three PHM generations after the last positive find.

If sex pheromone traps with virgin females are available and a Technical Advisory Committee recommends their use, such traps may be set in the core area at the rate of 32 to 36 traps per square mile in places where the safety of the traps are reasonably ensured. This statement is also contingent on the availability of a key to the males of mealybug species present in the program area which would include the PHM.

If a synthetic sex pheromone is available, the restrictions given above need not apply and traps may be set out in a standard grid pattern within the core and buffer areas as given above. The traps will be serviced weekly and replaced monthly. They may alternate with the cardboard traps in the grid system. In the event of an eradication program, these traps will also be maintained for the equivalent of at least three PHM generations after the last positive find.

Delimiting Survey (continued)



Cross Transit Survey:

Cross transit surveys are recommended for a rapid delimitation survey for the PHM when a find is verified or suspected. The objective is to find and delimit the infested area in the shortest possible time with minimum labor and expense but with a high degree of confidence that, if present, the pest will be found..

The survey proposed here is biased in the same way as it is for the detection survey. It is biased towards the primary host(s) of concern and in areas where the mealybug, if introduced, might be expected to be found first. Owing to the possibility of air dispersal, a special survey may be warranted for certain areas.

There are three types of areas to cover in this kind of survey:

- **High Risk Areas** — Major cities and towns where residents and visitors may be expected to travel to and from geographical areas where the mealybug already exists. Locations where known host plants are planted around hotels, airports, seaports, train and bus stations, and other transportation centers are especially important (Hall, 1921).

- **Downwind Areas** — Those areas where winds may reasonably be expected to carry the PHM from locations where it already exists.

Delimiting Survey (continued)

- **Host Areas** — These areas would include residential, nursery, and commercial properties (such as hotels), plus agricultural areas where known host plants, especially favored hosts, are grown. There should be a bias for residential properties if host are grown for food or as an ornamental in back yards (i.e., string beans, sorrel, hibiscus).

Block Survey:

The following measures should be taken if a find is verified and the cross transit survey indicates the infested area is small and perhaps well defined:

- If appropriate, conduct a block-to-block survey in the suburban/urban areas up to 7.2 km (4.5 miles) from each find.

- In rural areas, conduct a property-by-property survey up to 7.2 km (4.5 miles) from each find.

- Each block or property can be scored, if PHM is present, as:

  Light—1 to 5 host plants found infested/block. One to 10 egg masses or 1 to 100 nymphs and adults combined on only one host plant/block.

  Medium—11 to 100 egg masses or 101 to 2,000 nymphs and adults on 6 to 20 host plants (any combination of hosts or host species)/block.

  Heavy—2,001 plus nymphs and adults. 101 egg masses or more or 21 or more host plants infected/block.

The survey will permit the project to plot the area, extent, and nature of the infestation more accurately.

The frequency of the delimiting survey will depend on the time it takes to cover the area, the resources available for repeat surveys, and whether a decision is made to eradicate, suppress, or carry out a biological control program for the PHM. A maximum interval should be 1 to 3 months between surveys, depending on the urgency and type of program utilized.

Monitoring/ Evaluation Survey

A decision to suppress or eradicate the PHM evaluation will require a monitoring/evaluation survey to check on the PHM population. A cross transit survey would generally be used.

Orientation of Survey Personnel

New personnel will be trained on the job by experienced personnel.

Survey Records Records noting the areas surveyed, sites trapped, dates, locations, and hosts in which detections were made will be maintained, along with accurate counts of infested plants/property/block and mealybug counts if appropriate.

REGULATORY PROCEDURES

Instructions to Officers

Regulatory actions should be required until the pest is eradicated or declared established with no further suppression or control actions. A Scientific Advisory Committee will decide on the scope and extent of regulatory activity, if and when suppression and/or control actions are suspended or discontinued. Officers must follow instructions for regulatory treatments or other procedures when authorizing the movement of regulated articles.

Understanding the instructions and procedures will serve as a basis for explaining such procedures to persons interested in moving articles affected by the quarantine and regulations. Only authorized treatment procedures may be used.

General instructions to be followed in regulatory treatments may be found in State regulatory manuals or in the Plant Protection and Quarantine, Animal and Plant Health Inspection Service, Treatment Manual.

Regulated Articles

A variety of articles may present direct or indirect risks of spreading the PHM. The movement of these articles will be regulated to prevent the infestation from spreading.

Note: Live mealybugs in a non-host will die. Eggs can persist for weeks on many types of substrate in protected places such as cracks or crevices and can be transported out of an infested area. Regulated articles include:

- Fresh fruit, leaves, stems and other plant parts of hosts listed in Addendum 3 which exist in the regulated area.

- Nursery plant hosts or other host material with fruit,leaves, stems, and other host plant parts, including propagative material intended for planting.

- Any other product, article, or means of conveyance of any character whatsoever when it is determined by an inspector that it presents a hazard of spread of the PHM and the person in possession thereof has been so notified.

  —Hosts and host material, including full or empty containers
  —Decorative containers for potted ornamentals, usually wicker
  —Floral products such as cut flowers
  —Firewood, logs, pulpwood, timber and timber products
  —Mobile homes
  —Trees, shrubs, and grasses
  —Outdoor household articles
  —Vehicles and other means of conveyance that present a high risk of spreading the mealybug
  —Other articles and products that present a high risk of spreading the mealybug

Quarantine Actions

Regulatory action will be required if one or more adult females are identified from field collections. (The male and other life stages may not be available and definite identification may not be possible.)

When detections are made, the following steps should be taken:

1. State notifications are issued by field personnel to the property owners or managers of all establishments within 4.5 miles (mi) of the epicenter that handles, moves, or processes host material which may include material or conveyances capable of spreading the PHM. Notifications will be issued pending authoritative confirmation or further instructions from the Head of the State Plant Protection Service or the Deputy Administrator, APHIS, PPQ.

2. If necessary, the Deputy Administrator will issue a letter directing PPQ field offices to initiate specific emergency action under the Federal Plant Pest Act (7 U.S.C. 150 dd) until an interim rule can be published in the Federal Register. For information on other legal authorities, see Section II, Parts A and B of the APHIS Emergency Programs Manual (for plant pests).

3. The Head of the State Plant Protection service or the Deputy Administrator of PPQ will notify other State cooperators of the PHM detections, actions taken, and actions contemplated.

4. A narrative description of the regulated area with supporting documents should be developed by State personnel. The regulated area will normally be within an approximate 4.5 mi radius around the find and may contain a 1 sq mi or greater core area where premises may be treated.

5. The State may need to publish an interim rule covering the emergency regulations. The interim rule will announce a date for submitting written comments.

6. After receipt of written comments, a final determination specifying the action decided upon will be published.

Regulated Establishments

Efforts to detect the pest within the regulated area will be made at establishments where host material is sold, handled, processed, or moved. Establishments that might be involved include airports, bus and railroad stations, landfill sites, fruit stands, farmer's markets, produce markets, flea markets, nurseries, and any other establishments that handle host material.

Use of Chemicals

The appropriate State manual and these New Pest Response Guidelines identify chemicals authorized for PHM control, methods and rates of application, and any special application instructions. Concurrence by the appropriate State regulatory agency is necessary for the use of any other chemical or procedure for regulatory purposes. If treatments selected or proposed, including those listed in these New Pest Response Guidelines, are not in compliance with current pesticide labels, emergency exemptions will need to be obtained under Section 18, or 24C, special local need (SLN) of Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), as amended. Regulated articles may be certified for movement after treatment.

Approved Regulatory Treatments

Sanitation:

The removal and destruction of fruit, leaves stems, and other plant parts that may be associated with regulated items.

Steam Sterilization:

The use of steam, as a treatment alone, to conveyances, storage, or other holding areas.

Cleaning:

When appropriate, the use of hot soapy water as a treatment, to conveyances, storage or other holding areas, or to host material to effectively destroy any life stages of PHM that may be present.

Fumigation:

The application of an approved fumigant (methyl bromide) as a treatment alone, to hosts.

Hot Water:

The application of hot water at a specified temperature, as a treatment alone, to hosts.

Ground Spray:

An approved insecticide or biological insecticide applied to the above-ground parts of nursery stock.

Soil Treatment:

An approved insecticide applied to the soil of nursery stock.

Principal Activities

The following identifies principal activities necessary for conducting a regulatory program to prevent the spread of the PHM. The extent of regulatory activity required is dependent on the degree of infestation. For example, to safeguard fruit stands throughout the entire regulated area when these stands are only engaged in local retail activity may not be necessary during a localized and light infestation. On the other hand, mandatory checks of passenger baggage at airports and the judicious use of road patrols and roadblocks may be necessary where general or heavy infestations occur.

Principal regulatory activities include:

1. Contacting and advising regulated industry of regulations and required treatment procedures.

2. Issuing compliance agreements, certificates, and permits.

3. Supervising, monitoring, and certifying treatments of host material.

4. Conducting compliance inspections at regulated establishments such as:
   a. Nurseries
   b. Landscapers/Interiorscapers - especially for long-distance movement of large potted Hibiscus & other hosts
   c. Fruit stands
   d. Local growers and packers
   e. Farmers, produce and flea markets
   f. Commercial haulers of host material
   g. Public transportation
   h. Post office contacts
   i. Canneries and other processing establishments
   j. Yard and garden maintenance operations

5. Monitoring the movement of host material to approved landfills to ensure adequate disposal of regulated articles.

6. Monitoring the destruction of regulated articles to ensure adequate destruction of any life forms of PHM which may be present.

7. Monitoring the movement of regulated articles through airports, bus and train stations, seaports and marinas, and other transportation centers.

8. Monitoring hosts planted or present at airports, seaports, bus and train stations, and other transportation centers for the presence of PHM.

9. Notifying homeowners near detection sites of applicable regulations.

10. Visiting pharmacies and other establishments which may handle host leaves or other plant parts for medicinal purposes.

Removing Areas From Quarantine

Areas placed under regulation may be removed from quarantine requirements after the PHM has been declared eradicated or a decision made not to regulate the PHM and allow biocontrol agents to become established and disperse these widely across the infested area. Program management will identify areas to be removed when the equivalent of 6 months (24 weeks) has passed since the last specimen recovery. Two months must have elapsed since the cessation of control activities. A Notice of Quarantine Revocation will need to be published when areas are removed from quarantine requirements.

Orientation of Regulatory Personnel

Only trained or experienced personnel will be used initially. Replacement personnel will be trained by the individual being replaced.

Regulatory Records

Records will be maintained as necessary to carry out an effective, efficient, and responsible regulatory program.

Records my include:

- Maps
- Chronology of events and actions
- Personnel movement
- Treatment records
- Regulatory activities
- Meeting notes

CONTROL PROCEDURES

As control procedures are developed, they will be made available to involved States. Any Federal participation in direct control programs will be at the discretion of the Agency concerned. If treatments selected or proposed are not in compliance with current pesticide labels, an emergency exemption will need to be obtained under Section 18, or 24C, special local need (SLN), of FIFRA, as amended.

Complete eradication or suppression of a PHM infestation in the continental United States may not be possible. However, under some conditions, it may be feasible to eradicate or control a small local infestation.

The following provides approved procedures available for use in most situations. These procedures include biological, mechanical, and chemical controls. Local conditions will determine the most acceptable procedure or combination of procedures to achieve suppression, control or eradication.

Recommended Pesticides

The treatments prescribed are predicated on an adequate survey. At the initiation of a program, an evaluation available insecticides for use on program operations will be made.

Selection of Options

Program options may be selected through a decision-making process, such as embodied in Table 5—1.

Table 5—1: PHM decision-making process

If the infestations are:	And the pest population appears to be:	And the hosts are:	Then the option is:
Established in a large contiguous area	→	→	NO ACTION
Present in a number of widely separate and discrete areas	Well established, as measured by: • population, • estimates, • competition, • environment, or • climatological considerations	→	
Established in a small contiguous area	Not well established and population estimates felt to be a result of recent establishment (within 1 year)	Large number of hosts over an extensive area	Biological and cultural controls
		Moderate number of hosts over a well-defined area	Suppression, cultural, and biological controls
Present in only one or a few closely separate and discrete areas		Confined to a limited number of hosts	Control, suppression, and eradication

This decision table follows certain limited basic statements, and can be considered generally true in a biological sense, provided no other factors intervene. There are some underlying assumptions. For example, it is assumed that the PHM will be able to survive in the same ecological and environmental circumstances as its host(s).

No Action

Factors involved in arriving at a decision of "No cooperative program action" include the following:

Given that the PHM has firmly established itself in the infested area and that:

1. It is determined no reasonable effort will be successful in eradicating it (vs. a reasonable effort may be successful);

or

No Action (continued)

2. Regulatory or suppressive measures will not be economically sound, based on the area involved or the rate of spread (vs. affordable measures);

or

3. On the basis of measurable ecological factors, that the PHM will not be present in sufficient amounts in the environment to warrant control or suppression efforts (vs. a serious threat);

or

4. Control of the PHM is best left to standard means of control (such as host treatment) and other regulatory resources that control the spread and effects of the pest (vs. an urgent need to augment natural controls).

If any of these statements are not true and the contrary is true instead, then a decision to take "No Action" should be carefully evaluated.

Approved Eradication/ Suppression/ Control Options

Various combinations of treatments exist to arrive at a predetermined goal for a specific program that may be eradication, suppression, or control. This goal, and the strategies useful for eradication, containment, or control, will be determined by State and local personnel or their Technical Advisory Committees or equivalent advisory boards.

Approved Treatments

The following is a list of suggested treatments that may be applicable under certain conditions. The treatments selected will be determined by State and local personnel concerned with a given program and their Technical Advisory Committees or equivalent advisory boards. Addendum 5 lists certain additional treatments which may be available.

1. Biological and cultural controls should play as large a role in program efforts as possible. It is worth noting that mortality of larvae in large populations due to parasitization or predation may be high. This effect could be enhanced or augmented with other available means such as biopesticides, mating disruption, or cultural practices as listed below.

a. Biological Insecticides

(1). Bacteria
(2). Viruses
(3). Protozoa
(4). Nematodes
(5). Fungi
(6). Juvenile Hormones
(7). Pheromone Disruption
(8). Plant Extracts

b. Introduction of Exotic Natural Enemies

This technique is carried out by USDA, Agricultural Research Service and other agencies, institutions, and State cooperators. APHIS, PPQ is active in implementing classical biological control. The need here would be to find exotic natural enemies known to attack the PHM, which would be released and established. This would provide a permanent self-sustaining suppression of the pest population density below economic damage levels.

Possible parasites or predators whose efficacy under local conditions would need to be tested against the PHM are listed here. This list has been taken from the available literature.

Parasites:

Hymenopterous Parasites—

(1). *Alamella flava* (Encyrtidae) (Mani, 1989) From India. Of minor importance (Mani, et al., 1987).

(2). *Allotropa citri* (Platygasteridae) (Mani, 1989) From India.

(3). *Allotropa* sp. nr. *japonica* (Platygasteridae) (Mani, 1989) From India. Of minor importance (Mani, et al., 1987).

(4). *Anagyrus* sp. (Encyrtidae) (Mani, 1989) From India. Found to parasitize 19-47 percent of the mealybug on fibre crops. (Mani, 1989)

(5). *Anagyrus* sp. (Encyrtidae) (Beardsley, 1985) From Hawaii. Less plentiful than *A. kamali*, with which it was associated.

(6). *Anagyrus agraensis* (Encyrtidae) (Cross & Noyes, 1995) From the Oriental Region. Sympatric to *A. dactylopii* and *A. kamali*.

(7). *Anagyrus dactylopii* (Encyrtidae) (Mani, 1989) A Hong Kong parasitoid (Noyes & Hayet, 1994) introduced into India from Brazil in 1984 for control of the mealybug *Planococcus citri* (Mani, 1994). Found to parasitize up to 70 percent of the third instar and adult female of the PHM on grapes. A generation is completed in about 15 days. Dichlorvos is apparently non-toxic to this parasitoid. (Mani, 1989) Available in the USA (Acosta, 1996).

(8). *Anagyrus fusciventris* (Encyrtidae) (Noyes & Hayat, 1994) An Australian/New Zealand parasitoid introduced into Hawaii, California, Florida, Bermuda, Trinidad, Puerto Rico, Ghana, Italy and Israel for control of several mealybugs, (but not the PHM). It may have been introduced into Hong Kong, where a specimen was reared from the PHM on Oleander.

(9). *Anagyrus greeni* (Encyrtidae) (Mani, 1989) From India.

(10). *Anagyrus kamali* (Encyrtidae) (Mani, 1989) From Java. Introduced to Egypt and may have caused a decline in the PHM population, which was parasitized to 66-100 percent. In many places the mealybug disappeared completely. (Mani, 1989) Accidently introduced into Hawaii (Beardsley, 1985).

(11). *Anagyrus* (= *Gyranusoidea) mirzai* (Encyrtidae) (Noyes & Hayat, 1994; Mani, 1989) From India. Not a well known parasitoid of this mealybug. Of minor importance (Mani, et al, 1987).

(12). *Anagyrus pseudococci* (Encyrtidae) (Noyes & Hayat, 1994) From Egypt, Saudi Arabia.

(13). *Aphelinus* sp. (Aphelinidae) (Mani, 1989) From India.

(14). *Chartocerus* sp. nr. *walkeri* (Signiphoridae) (Mani, 1989) From India. Of minor importance (Mani, et al., 1987).

(15). *Cheiloneurus* sp. (Encyrtidae) (Mani, 1989) From India.

(16). *Erioporus aphelinoides* (Aphelinidae) (Mani, 1989) From India.

(17). *Gyranusoidea indica* (Encyrtidae) (Meyerdirk, pers. comm.) Meyerdirk (pers. comm., 1997) collected this species on PHM from Egypt. It is currently being reared for release on PHM populations in St. Kitts, West Indies.

(18). *Leptomastix phenacocci* (Encyrtidae) (Mani, 1989) From Java. Introduced to Egypt, but may be hyperparasitized by *Achrysopophagus javanicus*, *A. annulatus* and *Eriaporus aphelinoides*. (Mani, 1989)

(19). *Leptopilina* sp. (Eucoilidae) (Mani, 1989) From India. Of minor importance (Mani, et al, 1987).

(20). *Phanerotoma dentata* (Braconidae) (Mani, 1989) From Egypt.

(21). *Procheiloneurus annulatus* (Encyrtidae) (Noyes & Hayat, 1994) From Indonesia.

(22). *Procheiloneurus javanicus* (Encyrtidae) (Noyes & Hayat, 1994) From Indonesia.

(23). *Prochiloneurus* = (*Achrysopophagus*) sp. (Encyrtidae) (Mani, 1989) From India. With *Anagyrus kamali*, said to obtain outstanding control of the mealybug. (Mani, 1989)

(24). *Rhopus longiclavatus* (Encyrtidae) (Noyes & Hayat, 1994) From India. May eventually prove to be synonymous with *R. nigriclavus* (not listed here).

Predators:

Coleopterous Predators—

(1). *Brumus suturalis* (Coccinellidae) (Mani, 1989) From India.

(2). *Chrysopa* sp. (Coccinellidae) (Mani, et al., 1987) From India. Three species of this genus are available in the USA (Hunter, 1994).

(3). *Chrysopa scelestes* (Coccinellidae) (Rao, et al., 1984) From India.

(4). *Cryptolaemus affinis* (Coccinellidae) (Greve & Ismay, 1983) From Papua New Guinea.

(5). *Cryptolaemus montrouzieri* (Coccinellidae) (Mani, 1989) From France. This predator was not effective in Egypt, probably due to poor overwintering; but it was effective in India at the rate of 1000/ha. At 1500 per acre, it gave effective control within 75 days in vine yards. The predatory larva may eat up to 1500 nymphs of the mealybug during its development. May be adversely affected by low temperatures. Dichlorvos and chlorphyriphos are relatively nontoxic to this species. (Mani, 1989) It is established in the USA and is commercially available (Acosta, 1996).

(6). *Hippodamia convergens* (Coccinellidae) (Acosta, 1996) From USA. Easily available predators by mail order. Shipped in the adult stage in quantities depending on the area to be covered, i.e., 1/4 pt (650 sq ft; 2,300 ladybugs) to 1 gal (10-20 acres; 72,000 ladybugs). Ideal conditions are 61-72 degrees F. May be stored for 1-3 weeks at 35-45 degrees F.

(7). *Hyperaspis maindronii* (Coccinellidae) (Mani, 1989) From India. A different species (*H. miles*) is available in the USA (Hunter, 1994).

(8). *Melanophthalma carinulata* (Lathridiidae) (Mani, 1989) From Egypt.

(9). *Menochilus sexmaculata* (Coccinellidae) (Mani, 1989) From India.

(10). *Nephus regularis* (Coccinellidae) (Anon., 1996) From India.

(11). *Oxynychus erythrocephalus* (Coccinellidae) (Mani, 1989) From Egypt.

(12). *Pullus ? salomonis* (Coccinellidae) (Greve & Ismay, 1983) From India.

(13). *Rodolia cardinalis* (Coccinellidae) (Mani, 1989) From Egypt.

(14). *Scymnus* sp. (Coccinellidae) (Greve & Ismay, 1983) From Papua New Guinea.

(15). *Scymnus biverrucata* (Coccinellidae) (Mani, 1989) From Egypt.

(16). *Scymnus coccivora* (Coccinellidae) (Mani, 1989) Recommended for control in India, since *Scymnus* species can survive at low population levels of PHM and are not adversely affected by low temperatures. A single predatory larva consumes about 60-70 mealybug nymphs during a developmental period of about 20 days. (Mani, 1989) This species has been imported from India to Trinidad and Tobago and St. Kitts in 1995 and 1996 (Dale Meyerdirk, per. comm.)

(17). *Scymnus gratiousus* (Coccinellidae) (Mani, 1989) Recommended for control in India, since *Scymnus* species can survive at low population levels of PHM and is not adversely affected by low temperatures. (Mani, 1989)

(18). *Scymnus nubilus* (Coccinellidae) (Mani, 1989) From India.

(19). *Scymnus* sp. nr. *nubilus* (Coccinellidae) (Mani, 1989) From India.

(20). *Scymnus pallidicollis* (Coccinellidae) (Mani, 1989) From India.

(21). *Scymnus pyrocheilus* (Coccinellidae) (Mani, 1989) From India.

(22). *Scymnus seriacus* (Coccinellidae) (Mani, 1989) From Egypt.

(23). *Sericoderus percikanus corylophidae* (Coccinellidae) (Mani, 1989) From Egypt.

Dipterous Predators—

(1). *Cacoxenus perpicaux* (Drosophilidae) (Mani, 1989) From India.

(2). *Coccodiplosis smithi* (Cecidomyiidae) From Papua New Guinea. (Greve & Ismay, 1983)

(3). *Diadiplosia* sp. (Cecidomyiidae) (Mani, 1989) From Egypt.

(4). *Diadiplosia indica* (Cecidomyiidae) (Mani, 1989) From India. Larvae eat eggs, nymphs and gravid females. Eggs are laid loosely on the ovisac of the mealybug. (Misra, 1920)

(5). *Triommata coccidivora* (Cecidomyiidae) (Mani, 1989) From India.

Hemipteran Predators—

(1). *Geocoris tricolor* (Coreidae) (Mani, 1989) From India.

Lepidopterous Predators—

(1). *Autoba silicula* (Noctuidae) (Mani, 1989) From India.

(2). *Eublemma* sp. (Noctuidae) (Mani, 1989) From Egypt.

(3). *Eublemma geyri* (Noctuidae) (Mani, 1989) From Egypt.

(4). *Eublemma* sp. nr. *trifaciata* (Noctuidae) (Mani, 1989) From India. The caterpillars are predaceous on the nymphs and females, which they devour avidly, and pupate in the midst of mealybug colonies, but fall prey to Drosophilid flies in turn. (Misra, 1920)

(5). *Spalgis epius* (Lycaenidae) (Pushpaveni, et al, 1974) From India. The caterpillars feed voraciously on young nymphs of the mealybug. Each full-grown caterpillar is capable of eating as many as 300 nymphs per day.

Neuropterous Predators—

(1). *Brinckochrysa scelestes* (Chrysopidae) (Mani, 1989) From India.

(2). *Chrysopa* sp. (Chrysopidae) (Mani, 1989) From India. This genus = *Chrysoperla*.

(3). *Chrysoperla carnea* (Chrysopidae) (Mani, 1989) From Egypt. Available in the USA (Hunter, 1994)

(4). *Chrysoperla* sp. From USA. These are available year-round in any life stage from suppliers. They are released in the egg stage at the rate of 1,000 eggs per 200 sq ft. Repeated releases may be necessary. (Acosta, 1996) Three species, including the above, are listed by Hunter, 1994.

(5). *Conwentzia psociformis* (Coniopterygidae) (Mani, 1989) From Egypt.

(6). *Mallada boninensis* (Chrysopidae) (Mani, 1989) From India.

(7). *Sympherobius pygmaeus* (Hemerobiidae) (Mani, 1989) From Egypt.

c. Augmentation of Predators or Parasites in Infested Area(s)

This technique is applied by mass rearing of the most highly efficient parasites or predators for mass release in infested areas. It is generally used when natural enemies are absent, occur too late, or are in numbers too small to provide effective pest control when needed.

Where the PHM is new or is expected to occur in an area, inoculative augmentation may be practiced with the intention of establishing populations of its enemies through subsequent generations for control. (Driesche & Bellows, 1996)

Inundative augmentation by flooding a chosen area with large numbers of one or more natural enemies is intended to exert rapid control of the pest in the present generation (like a pesticide) and prevent or bring down possible damaging host losses. (Driesche & Bellows, 1996)

d. Conservation of Predators and Parasites

This treatment refers to the conservation of natural enemies, native or introduced, through integrated procedures, highly selective predator- or parasite-friendly insecticides or techniques, biological insecticides, and cultural practices favoring predators and parasites.

(1) Trunk Injection

For woody hosts, trunk injection of selected insecticides will effectively curtail the pest population attacking an injected host while protecting the predator/parasite population, except those individuals which may feed on or parasitize poisoned pests. See Addendum 5 for technical information.

(2) Band Treatment

This treatment consists of the free application of insecticide to the tree trunk with a trunk applicator or paint brush. It is obviously less selective and somewhat more likely to endanger a parasite/predator population. However, the area of application is still out of the way of most parasite-predator and prey activity. See Addendum 5 for technical information.

e. Chemical Integration

The direct application of selected chemicals to the host which are nontoxic or relatively nontoxic to selected parasites or predators which are also released in the area. Pesticides nontoxic to specific parasites or predators are listed below:

Cryptolaemus montrouzieri
Dichlorvos (Mani, 1989)
Chlorphyriphos (Mani, 1989)
Chlorobenzilate-oil (Meyerdirk, et al, 1979)

Anagyrus dactylopii
Dichlorvos (Mani, 1989)
Diazinon (Mani & Thorntakarya, 1988)
Phosalone (Mani & Thorntakarya, 1988)
Fish Oil Resin Soap (Mani & Thorntakarya, 1988)
Copper oxychloride (Mani & Thorntakarya, 1988)
Mancozeb (Mani & Thorntakarya, 1988)
Sulfer (Mani & Thorntakarya, 1988)
Carbendazim (Mani & Thorntakarya, 1988)
Bordeaux Mixture (Mani & Thorntakarya, 1988)
Dicofol (Mani & Thorntakarya, 1988)

Anagyrus pseudococci
Chlorobenzilate-oil (Meyerdirk, et al, 1979)

Scymnus coccivora
Copper oxychloride (Mani & Thorntakarya, 1988)
Mancozeb (Mani & Thorntakarya, 1988)
Sulfur (Mani & Thorntakarya, 1988)
Carbendazim (Mani & Thorntakarya, 1988)
Bordeaux Mixture (Mani & Thorntakarya, 1988)
Dicofol (Mani & Thorntakarya, 1988)

f. Enablement of Predators and Parasites

This treatment refers to augmenting the ability of predators and parasites to attack the host with greater efficiency or to be more tolerant of insecticides or other practices through selective breeding of the most efficient predators and parasites. Gene manipulation may also be involved (Hoy, 1990a, 1990b; Caprio, et al, 1991). The work of Marjorie Hoy (now at the University of Florida, Gainesville) in this area on genetic improvement of natural arthropod enemies is instrumental to the concept, and her expertise should be consulted in designing any enablement program.

g. Ant Control

As an adjutant to biological control options, ant control measures may be required to prevent ants from protecting the PHM from parasites and predators. There are several types of options, depending on the situation (see Addendum 5).

h. Insecticides

The following are effective against the PHM. Specific information is mentioned, where possible, under each insecticide. Some compounds, such as growth regulators, should be preferred if they exhibit little or no toxicity towards any predators and parasites that may be present or introduced in an area. Additional insecticides for mealybugs (but not for PHM specifically) are given in Addendum 5.

Application of any of these compounds should take into consideration the life habits of the mealybug to include by spraying whenever possible and practical, protected habitat such as cracks in the bark, in crevices, between fruit clusters, under the calyx of the fruit and even under heavy, sooty-mold encrustations. (Meyerdirk, et al., 1981b)

Notes: Foliar applications may need to be mixed with surfactants to penetrate the waxy covering of PHM, unless otherwise specified.

The crawler stage is the most susceptible and sprays applied at times of most crawler activity will be the most successful in controlling the population.

Hosts with susceptible roots or tubers (potatoes, some grasses- Hall, 1921; peanuts - Rao & Srinivasan, 1987; beans, cotton - Hosny, 1939) may need to be treated with granular formulations.

The ovisacs, which contain the eggs, are provided with additional protection as they are composed of waxy filamentous secretions and the natural body wax of the mealybug in addition to the sooty-mold. (Meyerdirk, et al, 1981b)

The above suggests that a drench to the host is the best possible application. Depending on hosts and situations involved, however, a drench may not always be possible or practical.

Note: The PHM has demonstrated resistance against chlorinated hydrocarbons years ago, including DDT and toxaphene in 1951. (McKenzie, 1967)

(1). Aldicarb

One application in soil of granular formulation at 50 gms per vine protects grape bunches. However, residues in bunches were not determined. (Mani, 1989)

(2). Citrus Oil

Citrus oil was found to be 95 percent effective against the 1st stage of the citrus mealybug (*Planococcus citri*) at a rate of 74.8 L/ha by Meyerdirk, et al., 1981b. The authors suggested citrus oil + chlorbenzilate at 2.24 kg AI/ha to control both citrus mealybug and citrus rust mite on citrus and to time the application for the first nymphal stage and yet be relatively safe to the natural enemy complex. It is <u>not</u> known how the PHM will respond to this treatment.

(3). Dichlorvos

Dichlorvos is applied at a rate of 0.2 percent in combination with fish oil rosin soap at a rate of 25 g/L in a spray formulation. (Mani, 1989)

(4). Safer BioNeem

This is a new botanical growth regulator with Azadirachtin as the active ingredient. Generally, apply 8 oz. of product per 3,000 sq ft (Acosta, 1996). It is <u>not</u> known how PHM will respond to this treatment.

(5). Garlic Barrier®

This is a new botanical repellent for which mealybugs are listed as a target insect. Dilute product in water at a ratio of 100 product: 1 water. Use a fine spray mist by air or on the ground. One application should be applied early in the season and three more about 3-4 weeks apart. Advantages are safety, low cost, and lack of odor. Disadvantages are unknown effect on the PHM and repellent effect to the PHM predator and parasite complex. (Web Feat, 1996)

i. Cultural Control

(1). Bird predation

Should a resident bird population appear to effectively reduce the numbers of a targeted pest, then the bird population in question should be disturbed as little as possible. If it is felt desirable, the birds can be encouraged to increase in numbers through provision of food during winter months, the protection of nesting sites, and the discouragement of various bird predators or possibly, of diseases.

(2). Patch Complex

A variation of the above, especially for biological forest protection, involves the employment of patch complexes in which a number of areas are set up inside the entire control area to promote certain ecological situations advantageous for control within the economic constraints of a program. Inside the patch (or area), a complex of increased natural diversity is encouraged. Methods include the introduction of underwood species, increasing the provision of nesting sites for birds and the encouragement or discouragement of ant colonies depending on their perceived role in either protecting or preying on the mealybug or natural enemies.

(3). Host Destruction

In situations with a very limited infested area and when the hosts are all herbaceous, vinelike or decumbent, consideration may be given to host destruction by herbicides; disking or plowing; and removal and burial or incineration. In cases of such destruction, all host material must be completely destroyed.

(4). Sanitation

Sanitation in nurseries, farms, gardens, and other establishments where hosts are present will be carried out within the core and buffer areas. While it is impossible to completely clean out an infestation by this means, the mealybug population can be reduced through trimming and pruning of twigs, leaves, branches, fruiting areas and even removal of plants, especially seriously affected ones. Whole trees, as the single most serious source of continued widespread infestations, should be carefully cut to avoid scattering ovisacs and crawlers. In general, any cutting and pruning should not be done when strong winds or breezes are present as this will also scatter the various life stages of the mealybug while the work is going on.

Sanitation will also consist of the following measures, to be applied depending on the circumstances and equipment available.

(a) Burning of Debris

When PHM infested host material is collected, it may be piled into heaps and burned if local ordinances permit. The residue can be disked under or otherwise buried in an approved landfill. Care should be taken not to unduly disturb ovisacs or crawlers which could result in scattering eggs or crawlers so that they escape destruction.

(b) Animal Food

Some kinds of host material may be used as animal food. Any residue will be disposed of by burning or burial at an approved landfill. Unless food is processed, care should be taken not to unduly disturb ovisacs or crawlers which could result in scattering eggs or crawlers so that they escape destruction.

(c) Bagged and Buried

PHM infested host material may be collected in suitable containers and transported to an approved landfill. Care should be taken not to unduly disturb ovisacs or crawlers which could result in scattering eggs or crawlers so that they escape burial.

(d) Vehicle/Outdoor Object Inspection/Cleaning

Vehicles, trucks, wagons, outdoor furniture, containers, and other things left outdoors, that are used in host fields, stands, orchards, woods, or yards within the regulated area must be inspected to ensure that accidental movement of ovisacs, crawlers, or other life stages does not occur. Cleaning consists of the removal and destruction of any ovisacs and mealybugs found, including any substrate, such as leaves, twigs, flowers, buds, fruit on which they may occur.

(e) Host Inspection/Cleaning

In cases of limited infestations, an inspection of hosts or nearby nonhosts may turn up suspect ovisacs, crawlers, or other life stages. Cleaning the trunks and stems can do much to reduce the infestation especially if done in autumn after harvest time for the following year.

Orientation of Control/ Eradication Personnel

Only trained and experienced personnel will be utilized initially. Replacement personnel will be trained by the individual being replaced.

Eradication/ Control Records

Records noting the locations, dates, number and type of treatments, and materials and formulations used will be maintained for all areas treated.

Monitoring

An effective monitoring program will be implemented to aid in the evaluation of program efforts and environmental impact. The application of pesticides will be assessed through the use of appropriate monitoring program criteria. The evaluation must effectively address Agency, cooperator, and public concerns. Special techniques for monitoring the effect of insecticides on forest fauna will likely be applicable.

The program plan should include at least the following elements:

1. Determine the efficacy or effect of parasites or predators used against the target pest. The use of cardboard traps for this purpose will be sufficient. (Debach, 1949)

2. Determine the efficacy of any pesticide used against the target pest.

3. Evaluate dye needs to monitor aerial applications, especially;

   a. Droplet size
   b. Droplet distribution
   c. Identification of drift components
   d. Verification of spray block boundaries
   e. Identification of skips

4. Sampling to evaluate the effect of a PHM program on the environment will be conducted in accordance with an environmental monitoring plan. These plans include pre- and post-application sampling and observations to determine the impact on soil, water, vegetation, and nontarget species. Carcass searches are a part of this monitoring.

CONTACTS

When a PHM program is implemented, its success will depend on the cooperation, assistance, and understanding of many involved groups. The following groups should be continually informed of all operational phases of an emergency program.

1. Federal, State, county, and municipal agricultural officials;
2. Grower groups;
3. Commercial interests;
4. Universities;
5. State and local law enforcement officials;
6. Public health;
7. Foreign agricultural interests;
8. National, State, and local news media; and
9. The general public.

PATHWAY EVALUATION

Natural Means

The egg, crawler, and male (adult) stages of the PHM have the potential of being blown by wind currents in the upper atmosphere for up to hundreds of miles. In general, the eggs always have a portion of the fibrous ovisac adhering to them which will allow transport over considerable distances. Infested leaves borne away by the wind may also be responsible for spreading the infestation. Heavily infested old and large trees give the wind the best way to distribute the infestation over wide areas. Wind transport is indicated by the distribution of this mealybug in Egypt in the early 1900's, as it spread much farther to the South than to the North following the prevailing northern winds. (Hall, 1921). Such movement is also indicated by the movement of a related species, the Cassava mealybug, which spread up to 300 km a year to cover a vast area in Africa (Net/Showcase, 1996). Wind dispersal may be one of the reasons for the PHM spread in the Caribbean and the Hawaiian Islands. Spread to the United States from the Caribbean to the United States, however, may be unlikely by natural means owing to prevailing winds (EPPO, 1992; Gottwald, 1993) and demonstrated by subsequent events with brown citrus aphid in Florida and the Carribean.

The ovisac, which holds the eggs, is sticky. This could allow animals, especially birds, to accidently pick up a piece of ovisac on their feathers, fur, claws, or feet and carry eggs any distance at all before falling off or being cleaned off. If the eggs land on or near a host, crawlers could easily become established in the new area. The same could be said of crawlers actually crawling onto a bird's or other animal's feet or body part and being transported thereof. This hypothesis has <u>not</u> been proved, but distribution over large areas is probably not effected by this means or outbreaks would have occurred in the North (Delta Area) of Egypt as well as in upper Egypt. (Hall, 1921)

Transport by other insects has been reported including the nymphs and females of another mealybug, *Ferrisia virgatus*, which are said to carry the eggs and nymphs of the PHM to "new places." This is probably not significant, but does show how local movement can take place, like nymphs and females of the PHM, which have been observed walking from ditches or nearby areas to get to their hosts. (Misra, 1920)

Travel and Commerce

Annona species, especially sugar apple (*A. squamosa*) and custard apple (*A. reticulata*) made up more than one half of the interceptions (51 out of 90), on fruit in baggage based on data from the PPQ, PINET Database. Rambutan (*Nephelium lappaceum*) - 14 interceptions, followed by Guava (*Psidium guajava*) - 9 interceptions, were the next most common interceptions (again in fruit). This seems to indicate that the fruit of these hosts present the highest trade risk accounting for 82.2 percent of all interceptions. (Chang & Miller, 1996)

When combined with the statements in Natural Means, these interceptions suggest that the best pathway into the United States is through travel and commerce. This is more likely through Mexico especially if PHM is established there. That this is possible was indicated by a recent PHM interception which may or may not have originated from Baja, California. Hall, 1921, felt that this type of transport would be the chief means of distribution in the early days of a pest's invasion, before quarantine measures went into effect.

ADDENDUM 1

Definitions

Aerial Treatment—Applying an insecticide or pesticide by aircraft over a treatment area.

Array—The vector trapping pattern in the delimiting survey area located around a detection.

Array Sequence—The intensity of traps within an array, beginning with the core area and continuing outward through each buffer area, ending with the outer buffer area.

Buffer Area—The area extending a prescribed distance beyond the boundary of the core, the 1-, 2-, 3-, and 4-mile buffers.

Commercial Production Area—An area where host material is grown for wholesale or retail markets.

Confirmed Detection—A positive laboratory identification of a submitted life form as PHM.

Containment—The effective confinement of the PHM population(s) to a specified geographical locality through effective survey, regulatory, and control measures.

Control—The effective stabilization or containment of PHM population(s) in a specified geographical locality through effective survey, regulatory, and control measures.

Core Area—The 1-mi^2 area surrounding any confirmed PHM detection.

Day Degrees—An accumulation of heat units above a developmental threshold.

Delimiting Survey—Determining whether infestation exists and, if so, the extent of the geographical area the infestation occupies.

Detection—The collection and identification of any PHM.

Detection Survey—An activity to determine the presence of PHM, conducted in a susceptible area not known to be infested.

Developmental Threshold—The minimum (or maximum) temperature below (or above) which physiological development stops (peaks).

Epicenter/Focal Point—The initial site of an infection.

Eradication—The confirmed removal of all PHM life forms in a specified geographical area as determined by a negative survey for 6 months (24 weeds) or the equivalent of at least three life cycles.

Definitions (continued)

Fumigation—The application of an approved fumigant to hosts.

Generation (Life Cycle)—The period of time required for the pest to complete all stages of development.

Ground Spray—Using ground spray equipment to apply an insecticide or pesticide to the above-ground parts of host vegetation in a PHM-infested area.

High-Risk Area—Any area or location that could harbor the PHM as a result of the presence of hosts, the natural effect of wind, or thorough transport, storage, or presence of at-risk businesses or activity.

Host—A plant species capable of supporting PHM reproduction.

Infestation—The collection of one or more PHM life forms or the detection of a single life form determined to be associated with a current infestation.

Infested Area—A distance of 1½ miles from all detection sites unless biological factors indicate the need for more or less area.

Monitoring/Evaluation Survey—Using interdependent visual and perhaps trapping surveys in an area where a control, suppression, or eradication treatment is in progress to evaluate the effectiveness of the application.

PPQ-APHIS-USDA—Plant Protection and Quarantine, Animal and Plant Health Inspection Service, U.S. Department of Agriculture.

Regulated Area—An area that extends at least 4½ miles in all directions from an infested property.

Regulated Articles—All known or suspected hosts of PHM or any other suspected product or article.

Regulatory Inspection—Visual examination of host material and containers at establishments where regulated articles are grown, handled, processed, or moved. Under some circumstances this examination can include discretionary trapping around selected establishments.

Suppression—The effective reduction in numbers per unit area of a population(s) of the PHM in a specified geographical locality through effective survey, regulatory, and control measures.

Trap Survey—Determining the presence or absence of a pest by the use of traps placed in a predetermined pattern and serviced on a given schedule.

Urban/Residential Area—An area containing multiple or single family dwellings or commercial and industrial facilities.

Definitions (continued)

Visual Survey—Examining hosts for visual signs of infection, either in the field or in regulated establishments, or monitoring the movement of regulated articles.

ADDENDUM 2

Safety

Personal and public safety must be a prime consideration at all times. Safety practices should be stressed in preprogram planning and through the duration of actual program operations. Supervisors must enforce on-the-job safety procedures.

ADDENDUM 3

Hosts

Disclaimer:

The hosts recorded with damaging populations of the PHM are denoted with a number before the scientific name. They may or may not be economic hosts. The superscript number corresponds to the reference in which the host was stated to bear large numbers of the mealybug and this reference is given after the host list.

Any local survey needs to take into account not only the list given here but also those local plant species which may prove to be hosts. Since PHM demonstrates apparent changes in host preferences by locality, perhaps as a reflection of changes in habitat, environment, and interactions with the local flora/fauna/predator/parasite complex, a local host list should be designed, based on actual local finds, with this list of value only as a guide in the search for preferred and other local hosts.

Notes:

1. Some hosts may be attacked at their roots (potatoes, peanuts, beans, cotton, some grasses)

2. Symptoms may vary depending on the host (See Biology).

Ochro, [5] *Abelmoschus esculentus*
---, *Aberia* sp.
Velvetleaf, *Abutilon theophrasti* =(*avicennae*)
Acacia, *Acacia* sp.
Babul, [2] *Acacia nilotica* = (*arabica*)
Huisache, *Acacia farnesiana*
A copperleaf, *Acalypha* sp.
Cat's tail, [4] *Acalypha hispida*
Indian nettle, *Acalypha indica*
---, *Acalypha marginata*
---, *Acanthus ilicifolius*
Man better man, *Achyranthes indica*
---, *Acocanthera* sp.
Bael, *Aegle marmelos*
Silver Queen, *Aglaonema* sp.
Tantakayo, [4] *Albizia caribaea*
Lebbekh, [2] *Albizia lebbek*
Tantakayo, [5] *Albizia niopoides*
Saman, [4] *Albizia saman* = (*Samanea saman*)
Allamanda, *Allamanda* sp.
Yellow buttercup, *Allamanda cathartica*
Heart shae dasheen, *Alocasia cucullata*
Ginger lily, [4] *Alpinia* spp.
---, *Althaea* sp.
Bhagi, *Amaranthus* sp.

Atemoya, [5] *Annona* spp.
Cherimoya, *Annona cherimolia*
Soursop, [4] *Annona muricata*
Custard apple, [4] *Annona reticulata*
Sugar apple, [4] *Annona squamosa*
Anthurium, [4] *Anthurium andraeanum*
Peanut, *Arachis hypogaea*
Angelica, [4] *Aralia* sp.
Breadfruit, [4] *Artocarpus altilis*
Breadnut, [4] *Artocarpus communis*
Asparagus fern, [4] *Asparagus* sp.
Rice fern, *Asparagus densiflorus*
Asparagus, *Asparagus officinalis*
Bridel fern, *Asparagus setaceus*
Carambola, [4] *Averrhoa carambola*
Neem, *Azadirachta indica*
Poi spinach, [4] *Basella alba*
A bean, *Bauhinia* sp.
---, *Bauhinia acuminata*
Bauhinia, [2] *Bauhinia forficata pruinos*
---, Syn. = (*candicans*)
---, *Bauhinia racemosa*
---, *Bauhinia vahlii*
Orchid tree, [2,4] *Bauhinia variegata*
Begonia, *Begonia* sp.
Beetroot, [4] *Beta vulgaris*
Railway daisy, *Bidens pilesa*
---, *Bignonia* sp.
Ackee, *Blighia sapida*
Ramie, [1] *Boehmeria nivea*
Bougainvilla, *Bougainvillea* spp.
---, *Bougainvillea spectabilis*
Octopus tree, *Brassaia actinophylla*
Divi divi, [4] *Caesalpinia coriaria*
---, *Caesalpinia decapetala* = (*sepiaria*)
Pride of Barbados, *Caesalpinia pulcherrima*
Pigeon pea, [4] *Cajanus cajan*
Pigeon pea, [2] Syn. = *Cajanus indicus*
Powder puff, *Calliandra* sp.
Ylang-Ylang, [4] *Cananga odorata*
Bottle brush tree, *Callistemon* sp.
Seasoning peppers, *Capsicum* sp.
Sweet peppers, [4] *Capsicum annum*
Hot peppers, [5] *Capsicum fructescens*
Papaya, [4] *Carica papaya*
---, *Carissa acuminata*
Natal plum, *Carissa macrocarpa* =(*grandiflora*)

---, *Carissa ovata*
---, *Cassia* spp.
---, *Cassia glauca*
---, *Cassia renigera*
Casuarina, *Casuarina* sp.
Old maid, *Catharanthus roseus*
Kapok, *Ceiba pentandra*
Cox comb, *Celosia cristata*
Carob, [2] *Ceratonia siliqua*
Ladies of the Night, [4] *Cestrum nocturnum*
Sweet lime, [4] *Chaleas paniculata*
Lambsquarters, *Chenopodium album*
---, *Chrysanthemum* sp.
Crown daisy, *Chrysanthemum coronarium*
Generiad, *Chrysothemis pulchella*
Snake vine, *Cissus verticillata*
All Citrus sp., [4] *Citrus* spp.
Lime, *Citrus aurantifolia*
Sour orange, *Citrus aurantium* = (*bigarradia*)
Sweet orange, *Citrus sinensis*
Citron, *Citrus medica*
Tangerine, *Citrus reticulata* = (*nobilis*)
Grapefruit, *Citrus paradisi*
Bitter fence, *Clerodendrum aculeatum*
---, *Clerodendron infortunatum*
Butterfly pea, *Clitoria ternatea*
Seaside grape, [4] *Coccoloba uvifera*
Coconut, *Coccus nucifera*
Croton, *Codiaeum* spp.
Coffee, *Coffea* spp.
Arabica coffee, *Coffea arabica*
Croton, [4] *Codiaeum* spp.
Eddoe & dasheen, *Colocasia esculenta*
Mauby, [4] *Colubrina arborescens*
A jute, *Corchorus* sp.
---, *Corchorus olitorius*
Black sage, [4] *Cordia curassavica*
Cordyline, *Cordyline terminalis*
Cosmos, [4] *Cosmos* spp.
Cannonball tree, [4] *Couroupita guianensis*
---, *Crataegus* spp.
Calabush tree, *Crescentia cujete*
---, *Croton* sp.
Broom, [4] *Croton flavens*
Cucumber, [4] *Cucumis sativus*
Pumpkin, [4] *Cucurbita maxima*
Pumpkin, *Cucurbita moschata*

Squash, [4] *Cucurbita pepo*
Quince, *Cydonia* (= *Pyrus*) *oblonga*
Artichoke, *Cynara scolymus*
Sedges, *Cyperus* sp.
Gesneriad, *Chrysothemis pulchella*
---, *Dahlia* sp.
A grass, *Daradixa* sp.
Datura, *Datura* spp.
Carrot, [4] *Daucus carota*
Royal poinciana, *Delonix* (= *Poinciana*) *regia*
Orchid, *Dendrobium* cultivars
Dieffenbachia, *Dieffenbachia* spp.
Yam, *Dioscorea* spp.
Japanese persimmon, *Diospyros kaki*
---, *Dizygotheca elegantissima*
Dracaena, *Dracaena* sp.
Datur, *Duranta* sp.
---, *Duranta plumieri*
Duranta, [4] *Duranta repens*
---, *Elaeagnus* sp.
A weed, *Emilia* spp.
Bottle bush weed, *Equisteum arvense*
---, *Eranthemum pulchellum* = (*nervosum*)
Loquat, *Eriobotrya japonica*
Varigated immortelle, [4] *Erthrina variegata*
Chamelie, *Ervatamia coronaria*
Shadow beni, *Eryngium foetidum*
A bean, *Erythrina* sp.
---, [2] *Erythrina corallodendron*
---, [2] *Erythrina crista-galli*
---, [2] *Erythrina resinifera*
---, [2] *Erythrina speciosa* = (*reticulata*)
---, [2] *Erythrina stricta* = (*indica*)
Variegated immortelle, [5] *Erythrina variegata*
---, [2] *Erythrina vespertilio*
Coca, *Erythroxylum* sp.
Wax apple, [4] *Eugenia* spp.
Java plum, *Eugenia jambolana*
Pommerac, *Eugenia malaccensis*
Milkweed, *Euphorbia* spp.
Poinsettia, *Euphorbia pulcherrima*
Indian banyan, *Ficus benghalensis*
Banyan tree, *Ficus benjamin*
Weeping fig, *Ficus benjamina* = (*nitida*)
Common fig, *Ficus carica*
---, *Ficus cunia*
Rubber plant, *Ficus elastica*

---, *Ficus indica*
---, *Ficus laurifolia*
---, *Ficus platyphylla*
Peepul tree, *Ficus religiosa*
Sycamore fig, *Ficus sycomorus*
---, *Ficus virens* = (*infectoria*)
Series, *Flacourtia indica*
Gerbera, *Gerbera* sp.
Soyabean, [4] *Glycine max*
Glyricidia, [4] *Glyricidia sepium*
A cotton, [2] *Gossypium* sp.
Tree cotton, *Gossypium arboreum*
Levant cotton, *Gossypium herbaceum*
Silk-oak, [2] *Grevillea robusta*
---, *Grewia* sp.
---, *Haldina* (=*Adina*) *cordifolia*
---, *Hamelia* sp.
Heliconia, [4] *Heliconia* spp.
A hibiscus, *Hibiscus* spp.
---, *Hibiscus acetosella*
---, *Hibiscus boryanus*
Kenaf, [1,2] *Hibiscus cannabinus*
Blue mahoe, [4] *Hibiscus elatus*
Okra, [2,4] *Hibiscus esculentus*
---, *Hibiscus manihot*
Cotton-rose, [2] *Hibiscus mutabilis*
Hibiscus, [2,4] *Hibiscus rosa-sinensis*
Roselle, [2] *Hibiscus sabdariffa*
Roselle, [1] *Hibiscus* var. *altissimus*
Sorrel, [4] *Hibiscus* var. *sabdariffa*
Coral hibiscus, [2] *Hibiscus schizopetalus*
---, *Hibiscus surattensis*
Shrub althea, [2] *Hibiscus syriacus*
---, *Hibiscus tiliaceus*
Chinese Hat, [4] *Holmskia sanguinea*
---, *Inga* sp.
Morning glory tree, *Ipomoea* sp.
Sweet potato, [4] *Ipomoea batatas*
Ixora, [4] *Ixora* spp.
Jacaranda, *Jacaranda mimosifolia*
Lady of the night, *Jasminum* sp.
Jasmine, *Jasminum* sp.
Aiton, *Jasminum sambac*
Wonder of the world, *Kalanchoe* spp.
---, *Kigelia* spp.
Lettuce, [4] *Lactuca sativa*
Queen of flowers, [4] *Lagerstroemia speciosa*

Lantana, *Lanatara camara*
Stinging nettle, *Laportea aestuans*
Honeysuckle, [4] *Leonotis nepetifolia*
Leuceana, [4] *Leuceana glauca*
Ackee, *Lighia sapida*
Tomato, [4] *Lycopersicon esculentum*
West Indies cherry, ??
---, [4] *Malpighia glabia* = (*punicifolia*)
---, *Malvaviscus arboreus*
Mango, [4] *Mangifera indica*
Cassava, *Manihot esculenta*
Sapodilla, [4] *Manikara zapota*
Alfalfa, *Medicago sativa*
Chinaberry, *Melia azederach*
Genip, [4] *Meliococca bijugatus* = (*bijuga*)
Mal estomac, [4] *Miconia cornifolia*
A hempweed, *Mikania cordata*
Sensitive plant, *Mimosa pudica*
---, [1] *Mimosa rubicaulis*
A mulberry, [1] *Morus* sp.
White mulberry, [2] *Morus alba*
Black mulberry, *Morus nigra*
Sweet lime, *Murraya exotica*
Curry leaf, *Murraya koenigii*
Sweetlime, [5] *Murraya paniculata*
Banana, [4] *Musa* spp.
Mussaenda, [4] *Mussaenda* spp.
Myrtle, *Myrtus communis*
Fish tail fern, *Nephrolepis biserrata furcans*
Boston fern, *Nephrolepis exaltata*
An oleander, *Nerium odorum*
Oleander, *Nerium oleander*
---, *Opuntia* sp.
Shrimp plant, *Pachystachys lutea*
---, *Paritium* sp.
A bean, *Parkinsonia* sp.
Horsebean, [2] *Parkinsonia aculeata*
White head, [4] *Parthenium hysterophorus*
Passion fruit, [4] *Passiflora edulis* var. *edulis*
Barbadeen, *Passiflora granadilla*
Giant granadilla, *Passiflora quadrangularis*
---, *Pavonia* sp.
Shining bush, *Peperomia pellucida*
African rose, *Pereskia bleo*
Avocado, [4] *Persea americana*
Maouipoui, [4] *Petiveria alliacea*
Petrea, [4] *Petrea arborea*

Mung beans, *Phaseolus mungo*
String beans, [4] *Phaseolus vulgaris*
Philodendron, *Philodendron* spp.
Date palm, *Phoenix dactylifera*
Wild date palm, *Phoenix sylvestris*
Damson, [4] *Phyllanthus acidus*
Seed under leaf, [4] *Phyllanthus amarus*
Niruri, *Phyllanthus niruri*
Shining bush, *Piper pellucida*
Candle bush, *Piper tuberculatum*
Plumbago, *Plumbago auriculata* = (*capensis*)
Poinsettia, *Poinsettia* sp.
Pursley, *Portulaca oleraceae*
Jump and kiss, *Portulaca pilosa*
Apricot, *Prunus armeniaca*
Common plum, *Prunus domestica*
Peach, *Prunus persica*
Guava, [2,4] *Psidium guajava*
Pomegranate, *Punica granatum*
Pear, *Pyrus communis*
---, *Quisqualis* sp.
Boundary plant, *Rhoeo* sp.
Castorbean, *Ricinus communis*
Cats blood, [4] *Rivinia humilis*
Black locust, [2] *Robinia pseudoacacia*
Rose, *Rosa* spp.
Antigua heath, [4] *Russellia equisetifolia*
Sugarcane, *Saccharum officinarum*
---, *Salix* sp.
Schefflera, *Schefflera* sp.
Octopus tree, *Schefflera actinophylla*
False aralia, *Schefflera elegantissima*
California peppertree, *Schinus molle*
Brazilian peppertree, *Schinus terebenthifolius*
---, *Sciadophyllum pulchrum*
Devil's ivy, *Scindapsus aureus*
Sweet broom, *Scoparia dulcis*
---, *Senna italica*
Wild senna, [4] *Senna obtusifolia*
Cassia, *Senna siamea*
---, *Senna sulfurea*
---, *Sesbania sesban* = (*aegyptiaca*)
Broom weed, *Sida acuta*
---, *Solanum aethiopicum*
An ornamental, *Solanum bicolor*
Eggplant, *Solanum melongena*
Potato, *Solanum tuberosum*

Plum, *Spondias chili*
Golden apple, *Spondias cytherea* = (*dulcis*)
Hog plum, [4] *Spondias mombin*
Red plum, [4] *Spondias purpurea*
Yellow plum, [4] var. *lutea*
Vervine, *Stachytarpheta jamaicensis*
A weed, *Symedrella nodiflora*
---, *Syngoniun podophyllum*
Jamoon, [4] *Syzygium cumini*
French cashew, [4] *Syzygium malaccense*
Poui, *Tabebuia* sp.
White cedar, [4] *Tabebuia heterophylla*
Chamelie, *Tabernaemontana divaricata*
Tamarind, *Tamarindus indica*
---, [3] *Tecoma capensis*
---, *Tecoma grandiflora*
Trumpet flower, *Tecoma stans*
Teak, [4] *Tectona grandis*
---, *Templetonia* sp.
---, *Terminalia* spp.
Tropical almond, *Terminalia catappa*
---, *Terminalia mantaly*
Cocoa, [4] *Theobroma cacao*
Thunbergia, *Thunbegia erectia*
---, *Tithonia urticifolia*
Cowpea, [4] *Vigna uniguiculata*
Common periwinkle, *Vinca minor*
Grape, [4] *Vitis vinifera*
Tannia, *Xanthosoma* spp.
Corn, *Zea mays*
---, *Zizyphus* sp.
---, [2] *Zizyphus jujuba* = (*vulgaris*)
Indian jujube, [4] *Zizyphus mauritiana*
---, *Zizyphus mucronata*
---, [2] *Zizyphus spina-christi*

Hosts known Only by Common Name or Vague Designation

Orengo thyme
Pon-pom
Palm (Family-Palmae)
Numerous grass weeds
Leguminous weeds

[1] Ghose, 1972
[2] Hall, 1921
[3] Hall, 1926
[4] Persad, 1995
[5] Chang & Miller, 1996

ADDENDUM 4

Technical Survey Information

Cross Area Survey:

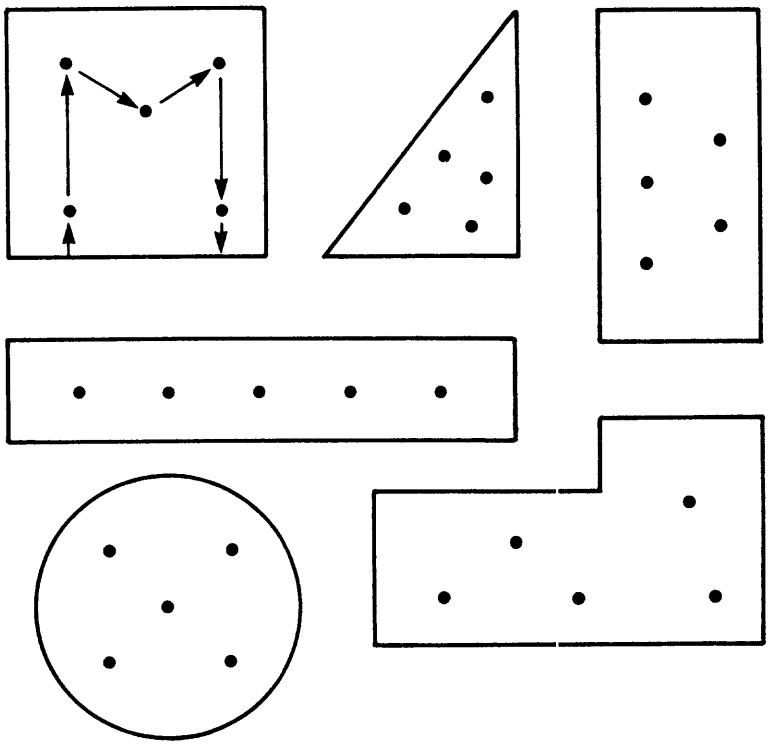
Using the site of the detection as the focal point, locate up to 16 host fields within the mi^2 core area. Each field will be sampled at five locations. A minimum of 50 plants (10 plants from each location) will be examined for the presence of ovisacs, crawlers, nymphs, and adult PHM.

Very large fields should be divided into smaller units and each unit counted as a separate field with a maximum of 10 acres. In order to keep spacing of sample fields roughly equal, not all units should be sampled at the same time.

To improve trapping effectiveness, conduct during favorable weather and periods of insect activity when and if such periods are determined.

If sufficient host fields are available, repeat the survey once a week in different fields. The survey will last for at least 3 months. Rotate fields to allow for coverage of the entire core area over each 4-week period.

Sampled areas should be equally spaced unless damaged hosts are noted. Such areas receive priority in the survey. Check borders, fence rows, and ditchbanks for suitable hosts. If suitable hosts are found, a separate survey may be taken. Sampling within the field should follow a similar pattern for each field being surveyed. When collecting samples within fields, take samples at least 75 feet from the edge, from five different locations in the field. Move from location to location following a predetermined pattern such as given below:



Technical Survey Information (continued)

At each of the five sample locations, inspect a minimum of 10 plants from three adjoining rows (or equivalent spacing if no rows are present) with a bias for those hosts showing the following signs:

- Poor growth
- Defoliation
- White egg masses on terminals
- Bunchy leaves
- Shortened or stunted terminal growth
- Dying or dead plants

Bear in mind that the distribution of the PHM population itself may be clumped in discrete areas. This clumping will tend to disappear if the population grows large as the season advances and many hosts are available.

Cross Transit Survey:

Draw two straight lines that will intersect each other and run through high risk areas:

- Host production (agricultural) areas
- Areas where hosts are in abundance (wild hosts, back yard hosts, commercial hosts, etc.)
- Downwind high risk areas up to 20 miles away
- Suburban/urban areas whose residents are likely to travel to and from mealybug infested areas
- Coastal and port of entry areas where hosts are available

Both lines should bisect the area under survey. They do not need to be perpendicular to each other but should both run through the most suitable local sites that have been identified.

Examine all hosts along the transit. If there are many hosts along the transit (as in a field or grove), select 1 out of every 10 most likely localities. A minimum sample along any one transit should be 10 host localities. Another approach is to draw up a list of 5-10 high preference hosts for the survey based on those hosts preferred by PHM in the program area and which, insofar as possible, are also not preferred hosts for local mealybug species.

Technical Survey Information (continued)

Survey Procedures:

1. If host(s) are in new flush

a. Examine all host localities, if possible. Unless otherwise recommended, the selection should be biased towards upwind and downwind borders of a given field or grove where the mealybug is likely to congregate, especially if a strongly predominant wind direction is present (N'Guessan, et al., 1992; Fargette, et al, 1993).

Each host locality may be sampled, depending on the type of host. Hosts are best sampled if aggregated in wild stands, residential properties, or in cultivated fields. These fields or stands should be sampled at a minimum of five different sites, following a predetermined pattern agreed to beforehand by program staff or a technical advisory committee.

b. Restrict examination to host(s), especially host with new growth. Looking for all the symptoms is the most important element in the detection of the mealybug because by the time colonies are evident, the pest is already established and is difficult to control. In particular, pay attention to new growth that appears stunted; has curling or crinkling in the leaves; appears rosetted; has swollen terminal buds or these are bending downwards; and when young stems are spiralled. As different hosts express different types of symptoms or different levels of symptoms depending on pest severity and general plant health, try to become familiar with the symptoms to be expected in a given host. In general, check host(s) which appear to be unhealthy.

c. Look for other tell-tale signs of mealybug, that is, individual mealybugs appearing as whitish specks on the host or terminals and leaves covered with white egg masses, nymphs, and adults. Ant actively running and forming trails leading up and down the host are also a telltale sign. Collect any white and especially pinkish-white forms you see, either by pruning the affected plant part or by picking off the leaf, bud, or flower. All samples should be put in individually marked and labeled paper bags for later study and identification. A dark colored beating sheet (the better to see the white mealybug) may be employed to collect mealybug specimens directly and to ferret out its presence when visual observation fails. To collect individual specimens from either the host or beating sheet, wet a fine brush with 70 percent isopropyl or ethyl alcohol and touch the mealybug with the tip. The specimen can then be placed in a collecting vial or jar. (See McKenzie, 1967)

If the host is a root crop, check the base of the plant around the main stem. If possible, use a shovel to push up the plant so that soil will fall away from the crown and roots. Check in the cracks and crevices of the bark and on the tubers/roots. Collect any mealybugs with a forceps as above. (See McKenzie, 1967)

Technical Survey Information (continued)

Precautions should be taken to ensure that the PHM is not accidently spread through collection methods or procedures.

d. Label each sample with the collector(s) name, the date, host, and the exact location in enough detail so that someone else can find the spot.

e. Send vials (bottles) to a designated center for identification and processing.

2. When host(s) are not in new flush

a. Examine the undersides of mature foliage and cracks and crevices of branches.

b. Examine all suspect secondary or reservoir hosts, such as herbaceous weeds and shrubs, show typical visual symptoms and are found in or near infected properties along the transit. This includes backyard and field locations that are relatively easy to examine.

c. Follow the procedures as given in 3.a.(3-5) above.

The survey should be run weekly or biweekly until it is determined, through negative finds, that the PHM is not present in a given area. Transit lines may be moved in the judgment of the survey officer responsible for that area in an attempt to cover more favorable hosts or new locations.

Inspection Procedures:

Visual surveys and aids are more effective during periods of low insect populations and mobility. Traps may be deployed when populations are high or flight times of males or crawler dispersal are estimated to peak at a given time.

1. Survey of new flush on hosts. Look for symptoms of the mealybug, and colonies (especially).

2. Generally, look for certain signs, such as white egg masses, clusters of mealybugs on terminals, plant stunting, leaf curling, distorted leaves, and other year round evidence characteristic of the PHM. These signs may be checked throughout the year.

3. Traps may be used for the purpose of determining the populational densities of the mealybug, to verify the presence of the pest in low numbers, or for research purposes to determine flight periods.

Traps:

1. Pheromone Trapping

At present, no synthetic pheromone is available for the PHM. There is a trap model available which could be used and which requires at least 10 or more virgin females to attract the males within a limited range.

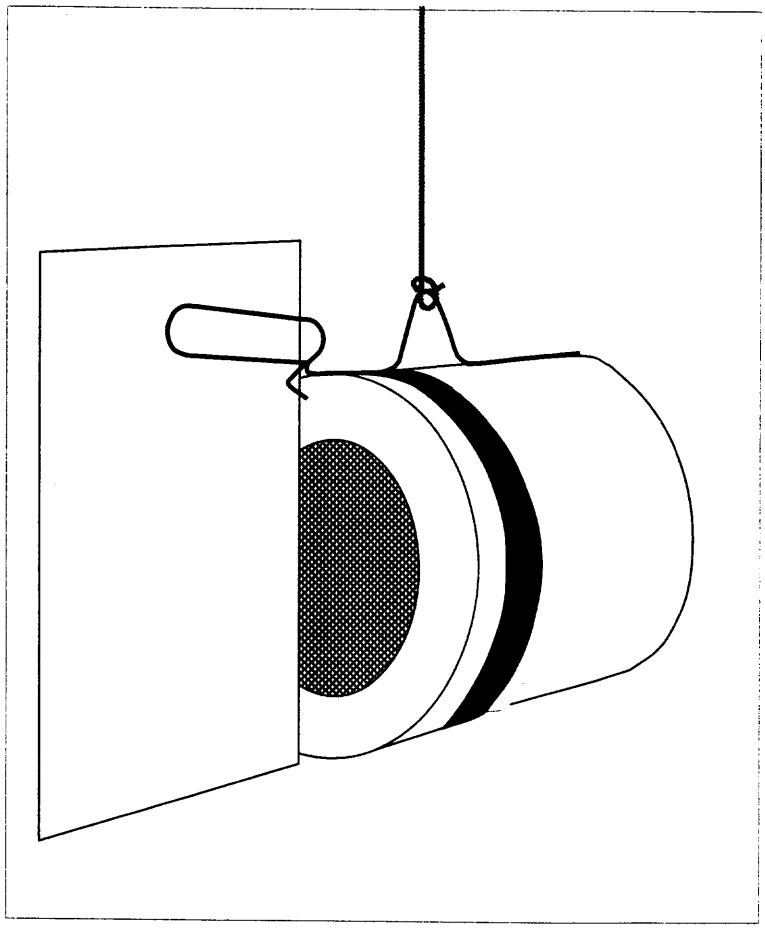
If made available, this survey tool could be used to discover an infestation if an area is to be declared eradicated of PHM. The idea behind this concept is that if the sex pheromone is species specific, then only PHM males will be attracted. Even if the male is without adequate taxonomic key characters, any mealybug males found in the trap would be a signal to look for a mealybug population with other life stages nearby that can be identified as PHM. Properly used, this trap can also be used to ascertain the population dynamics of PHM in a limited area. It is difficult, if not impossible (due to volume), to use this technique in the course of regular survey work.

Note: Additional research could easily develop a key to the local male mealybugs.

The trap consists of a 0.5 litre paper carton with a lid. The top of the lid is cut open and a fine 160 mesh cloth put in its place for ventilation. A sprouted potato (russet preferred) with the virgin females is placed inside the carton and the lid firmly attached and sealed to the carton. A white plastic card (7.6 X 10.6 cm), coated with Tack Trap® is attached to the carton with a metal clip (Do not use yellow sticky cards).

Each trap is hung within the canopy of host trees or from stakes 2 to 2.6 meters above the ground. The trap card is replaced weekly and the live females are replaced monthly. (Meyerdirk, et al., 1981a)

This type of trap is not without risk as the females conceivably could be freed from the trap by various means including accident, human, or animal intervention. This could lead to males mating with the exposed females and perhaps development to the crawler stage of the subsequent generation in some area away from discovery by the trapper. While slight, this possibility must be fully considered if the trap is used outside the regulated area. Traps should only be placed in locations where interference is unlikely. Traps should normally be restricted to infested areas only. The development of a synthetic sex pheromone is possible and would eliminate this risk.



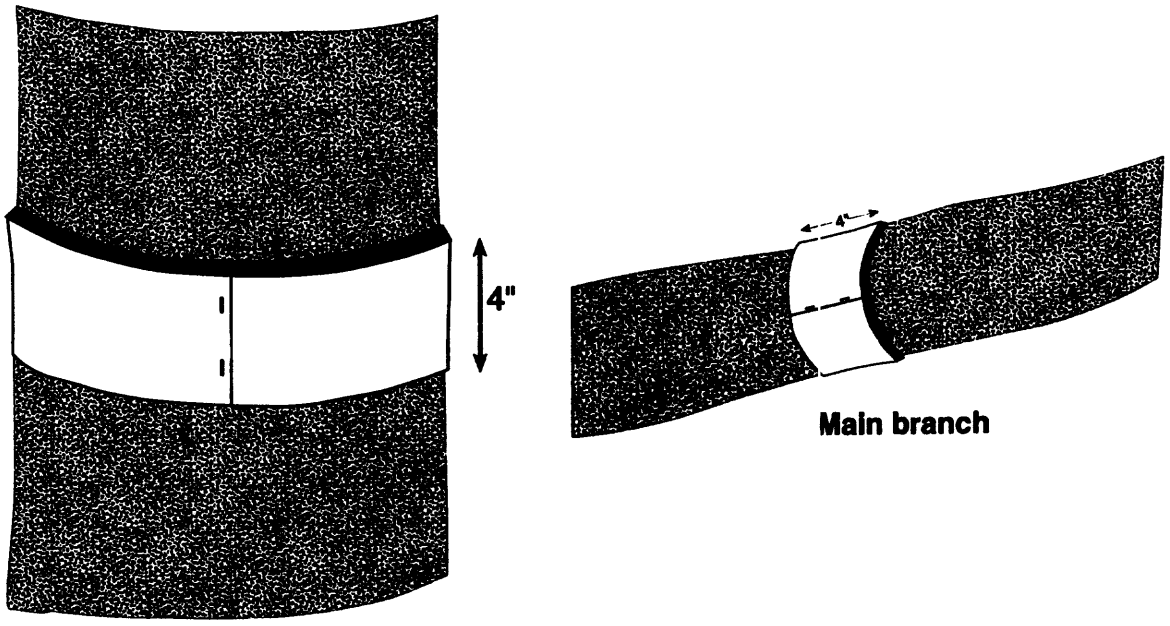
Mealybug sex pheromone trap with virgin females.

Another way to reduce risk is to sterilize the females. This has not been done for any mealybug to date. A procedure developed for scale insects and which may be applicable to mealybugs is to dip the females in a stable suspension of dichlorvos/water for a few seconds. The females are then allowed to dry out for 12 hours before use. (USDA, APHIS, 1985) This procedure has not yet been proven for the PHM and until this is done, cannot be employed.

Again, the development of a synthetic sex pheremone would, of course, alleviate this problem.

2. Cardboard band traps

A corrugated cardboard band, 4 inches (10.16 cm) wide, may be tied or stapled around the trunk or selected limbs and trunk of a selected host. The trap is replaced monthly and serves as an artificial microhabitat that may be used by adult female mealybugs in search of a shelter in laying their egg masses, or for mealybugs that have been parasitized and are seeking shelter. (DeBach, 1949; Meyerdirk, personal communication)



Cardboard Band Trap

3. Sticky traps

   Sticky traps are **not** recommended because of the following disadvantages:

   - They take too much labor to get satisfactory results
   - They do **not** trap females, the most identifiable life stage, unless they are fastened to the host (this is because the females do not fly)
   - It is too difficult to distinguish between adult males and crawlers of other mealybug species trapped in the area

Visual Survey:

With the current limitations on trapping as given above, the visual survey will remain the most important PHM survey process.

ADDENDUM 5

Bio-Control Information

For information on biocontrol including public and private organizations and suppliers, contact:

International Institute of Biological Control
Silwood Park
Buckhurst Road
Ascot, Berkshire
SL5 7TA
United Kingdom

Telephone: 44-(0)1344-872999
Fax: 44-(0)1344-875007
E-mail: cabi-iibc@cabi.org

National Biological Control Institute
USDA, APHIS
Office of the Administrator
4700 River Road, Unit 5
Riverdale, Maryland 20737-1229

Telephone: (301) 734-4329
Fax: (301) 734-7823
Bulletin Board System: (800) 344-6224
BBS (Local): (301) 734-4787
World Wide Web: http://www.aphis.usda.gov/nbci/nbci.html

Several supplier sources are:

California Environmental Protection Agency
Department of Pesticide Regulation
Environmental Monitoring
and Pest Management Branch
1020 N. Street, Room 161
Sacramento, California 95814-5604

Telephone: (916) 324-4100

Ask for "Suppliers of Beneficial Organisms in North America. This is also obtainable through the internet. For the latest update, contact:

World Wide Web: chunter@cdprsmtp.cdpr.ca.gov

Association of Natural Bio-control Producers
10202 Cowan Heights Drive
Santa Ana, California 92705

Telephone: (714) 544-8295

Ask for the member list. This is also obtainable through the internet. For the latest update, contact:

World Wide Web: http//ipm-www.ncsu.edu/biocontrol/anbp/HomePage.html

Bio-Control Procedures:

If it is decided to release biocontrol agents other than sprays, etc., then it is reasonable to select those organisms that is felt will do best under local conditions. The following applies:

1. Survey and document local parasites and predators and determine their role in the ecosystem.

2. Develop a complex of exotic parasites or predators that will complement rather than compete with the local complex or with each other. This means parasites attacking different life stages of the pest or predators in different situations. In many cases, of course, the result cannot be determined and a certain amount of trial and error will be involved. In addition, it may be advantageous to release directly competing natural enemies that are more efficient than the indigenous natural enemies. It may also be advantageous to release natural enemies that are co-evolved from the center of origin of the PHM and its relatives.

3. Prepare, in advance, rearing areas and equipment for the parasites and predators. This includes preparations for augmentation of local parasites and predators.

4. When material is obtained, rear enough in terms of thousands of each parasite and predator for intensive releases and hold back enough of each population for further rearing and releases.

5. Select release areas where the target population and its host(s) is the most abundant and not likely to be treated with insecticides. Use procedures appropriate for the parasite and predator being released.

6. Carryout followup surveys to determine survival of released parasites and predators and of the target population. The percentage of parasitism and predator activity in the field should be evaluated to determine which natural enemy is causing the greatest mortality. For parasites, mealybug mummies should be collected to rear out the parasites; and for predators, the effect should be judged by checking the results using open and closed sleeves on host limbs.

7. Augment successful parasites and predators with further releases and as deemed necessary.

Augmentative Bio-Control/ Special Delivery System:

If deemed advisable to augment natural dispersal, the use of Beneficial Insect Planes (BIP), a type of model airplane controlled by radio, may be used to release parasites with less mortality than with conventional airplanes. Such craft can cover a 50 acre field in 6-7 minutes (Anon., 1993) and release parasites at a low altitude with a low air speed.

Bio-Control Conservation of Predators and Parasites:

The following additional techniques can protect natural enemies by avoiding use of contact pesticides. This is limited to backyard situations, small areas, or specimen plants, owning to their labor intensive nature and expense. Herbaceous hosts cannot be treated in this manner.

Trunk Injection (Buitendag and Bronkhorst, 1980)

For woody hosts, trunk injection of selected insecticides will effectively curtail the pest population attacking an injected host, while protecting the predator and parasite population except those individuals that may feed on or parasitize poisoned pests.

Materials—

Dicrotophos or Monocrotophos 40 percent water soluble concentrate
20 ml disposable plastic syringes
Drill with 3.8 mm by 30 mm bit (minimum length)

Procedure:

Drill 3.8 mm by 25 mm deep holes in the host, following the chart on the next page.

Prepare a locking hole in the syringes. This is a small hole drilled through and near the top of the cylinder when the plunger is two thirds of the way out. The hole goes through both cylinder and plunger and is large enough to permit a nail to pass completely through the syringe.

Fill the syringe up to one third full (never more) with the undiluted insecticide; then fill it up completely with air.

The syringe is now ready for use. It is inserted with a turning action into the hole prepared for it. The air in it is then compressed with the plunger which is then held in position by passing the nail through the locking hole.

Absorption takes only a few minutes. This process is quicker when the hole is drilled through the longitudinal ridges of the trunk.

Note: It will take approximately 3 minutes per person to fill four syringes and attach them to the tree and only a few seconds to remove them after absorption.

Treatment will be repeated every 4 to 6 weeks or following the advice of an advisory panel.

Number of syringes needed:	When trunk diameter 25 cm above ground is:	When trunk diameter 25 cm above ground is:	Amount of insecticide in mL/tree is:
1	<50 mm	25 mm	0.5
2	50 mm to 75 mm	50 mm	1.25
4	75 mm to 175 mm	100 mm	3.75
		125 mm	5.0
		150 mm	7.5
6	>175 mm	200 mm	11.25
		250mm	15.0

Newer treatments since 1980 include Mauget Micro-Injection among others. The following applies to Mauget micro-injection procedures:

Materials—

Imidacloprid (IMICIDE @ 10 percent, Dicrotophos (INJECT-A-CIDE B), @ 82 percent or Abamectin (INJECT-A-CIDE AV @ 1.9 percent
Personal Protective Equiment
A portable drill
A rubber mallet
Injecter units, 2 3/4" long plastic tube with 1/4 to 3/8 width diameter and futed end
Double-sealed capsules with pre-measured amounts of the insecticide

Procedure—

Read "Directions for use and application of Mauget Injector Units" for specific details.

1/4" holes are drilled into a tree at 6 inch intervals with the mallet.

The injecter units are hammered into the tree with the mallet, flush to the base of the shield.

The capsules are fitted, upended, onto the end of each injecter unit to drain out.

Remove and dispose of capsules promptly after treatment.

Note: See the instructions given with the capsules for full details and follow all safety directions, including storage and disposal.

For program needs, contact:

J.J. Mauget Company
2810 North Figueroa Street
Los Angeles, California, USA 90065

Band treatment (Buitendag & Bronkhorst, 1986)

This treatment consisting of the free application of insecticide to the tree trunk with a trunk applicator or paint brush is obviously less selective and somewhat more likely to endanger a parasite and predator population. However, the area of application is still out of the way of most parasite and predator and prey activity.

Materials—

Dicrotophos (Azodrin at 400 g/L) or Imidacloprid (Merit, at label rates)
Azodrin fork applicator or Azodrin brush applicator (figured)

Fig. 1: Azodrin branch applicator

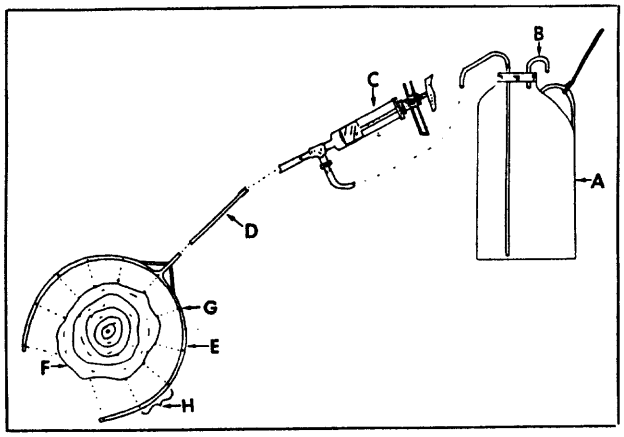


Figure 1: Azodrin trunk applicator for bearing trees.
A = Azodrin plastic container; B = Air inlet; C = 20 ml automatic syringe; D = 5 mm Diameter supply pipe; E = Spray fork; F = Tree trunk; G = 0,75 mm Orifice and H = 50 mm for small fork and 20 mm for large fork.

Fig. 2: Azodrin brush applicator

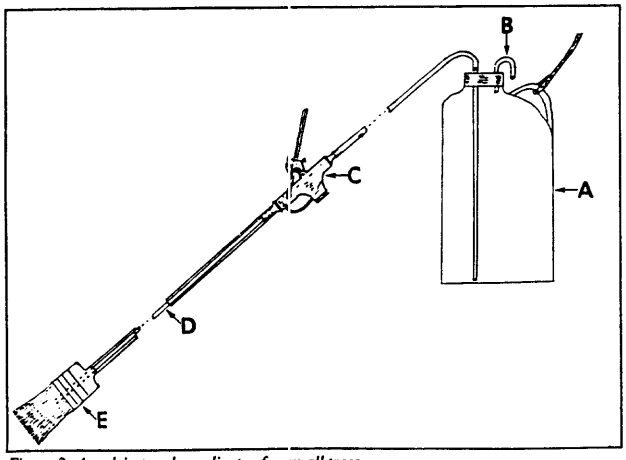


Figure 2: Azodrin trunk applicator for small trees
A = Azodrin plastic container; B = Air inlet; C = Stop valve; D = 5 mm Diameter supply pipe and E = Brush

Procedure—

Spray or brush the required amount of undiluted insecticide as given in the chart below. Cover the trunk with a wet band at the width given in the third column. Monthly treatments will be required.

Trunk circumference in mm:	mL of Azodrin needed:	Width of Azodrin band in mm:
30	0.1	9
40	0.15	13
50	0.3	16
100	0.8	32
150	1.0	48
200	2.8	64
250	4.8	80
300	6.5	96
350	10.0	111
400	15.5	127
450	24.0	143
500	35.0	159
550	50.0	175
600	70.0	191

Ant Control:

The following options may be employed.

1. Direct Treatment

   Since the ants tending mealybugs like sweet food, an attractive bait formulation may help to reduce their numbers. One such bait is Terro Ant Bait, a mixture of boric acid and sugar in a liquid solution (Acosta, 1996). The formulation should be scattered around the host (with some experimentation required) depending on the host, the ant species involved and on program needs.

2. Backyard Hosts

Trees may be banded in 1 foot wide bands at the base of the trunks with an appropriately registered insecticide or a sticky trap for ant control. There are a number of insecticides recommended for this use in the United States (Schwartz, 1982). These are:

Bendiocard	Fenthion
Carbaryl	Lindane (restricted use)
Chlorpyrifos	Malathion
Dichlorvos	Propoxur
Diazinon	Pyrethrins

In Brazil, it is recommended that dimethoate be sprayed on the trunk (Trevizoli & Gravena, 1979).

A recently developed South African control which avoids phytotoxic burns to the trunk is given below.

Bidim-plus-plastic wrap Band

A 4 inch wide strip of Bidim U24 (a polyester fiber) is wrapped around the tree with an overlap of over an inch. It is then covered with a double layer, 6 inch strip of plastic wrap. A 2.5 inch strip of Formex (a polybutene stickim) is then smeared over the masking tape but not on the Bidim. (Samways & Tate, 1984)

This barrier has a half life of 18 weeks under South African conditions.

Hosts other than trees (such as soybeans) cannot be treated directly, but ant mounds or nests on the premises should be treated with an appropriately registered insecticide or ant bait for nest control.

Commercial Hosts:

Broadcast application for ant control of an appropriately registered insecticide applied to the ground may be appropriate. Under certain limited situations where the acreage is not too great, individual application of ant bait to nests or mounds where ants are a problem may be employed.

Efficacy of viral sprays:

While much work remains to be done on efficacy and application of viral agents, the transmission dynamics of Nuclear Polyhedral Viruses (NPV) suggest that application at the late instar stages of a target population will be the most effective. This is because transmission to healthy late instars which are more likely to become infected is unaffected by the patchiness of the distribution of the mealybug population, whereas patchiness does affect transmission to early instars. (Dwyer, 1991)

Some experimental work is also being undertaken at the USDA Insect Biology and Population Management Research Laboratory in Tifton, Georgia, involving the use of honeybees. Talc, laden with a specific virus harmless to the bees is placed at the entrance to their hives. The bees are dusted with the talc on leaving the hive and spread it to the flowers and other places they may visit. Provided that a given virus is harmless to bees and toxic to the target pest and also that at least some hosts of the target pest are also frequented by bees, then this is a possible low-cost technique during host flowering. How efficacious such a treatment would be is unknown at present, but undoubtedly it would have to be employed in conjunction with other measures.

Pesticides:

The following are current (September, 1996) commercial foliage plant pest control suggestions for mealybugs, Table 12—1. Foliar applications may need to be mixed with surfactants to penetrate the waxy covering of PHM, unless otherwise specified. The Internet address is http://hammock.ifas.ufl.edu/txt/fairs/ig/25176.html.

Table 12—1

Product:	Formulation:	Application:
Foliar Sprays		
++Bendiocarb 76% WP (Dycarb, Turca)	Follow label directions	
Diazinon 4E	1 pt 1 tsp	
Dimethoate (Cygon 2 E)	2 pt 2 tsp	
Dursban 50 WSP Nursery	1 lb	Make a second application in 2 to 3 weeks. A third may be necessary if a non-systemic insecticide is applied.
Enstar II	Follow label directions	
Knox Out 2 FM	3 to 6 pt 1/2 — 1 fl oz	
Orthene turf, tree & ornamental spray	2/3 lb 2 tsp	
Talstar T&O Flowable	Follow label directions	
Foliar Dip		
Mavrik Aquaflow	5 fl oz	Submerge cuttings for 1 minute.
Root Drench		
Diazinon 4 E (AG 500)	2 pt 2 tsp	Apply as a soil drench. Apply second application in 1 week.
Diazinon 50 WP	2 lb 2 tsp	

Other insecticides selected from the literature are:

Metasystox—A systemic insecticide applied to the foliage at the rate of 0.05 percent gives 100 percent control of the PHM. (Veni, et al, 1973) This product has been discontinued in the United States, but because it does affect 100 percent control, it could be used under very specific conditions for highly prized plants. It breaks down quickly in alkaline water.

ADDENDUM 6

Special Considerations for Home Gardens

Factors in Regulatory Decisions:

Home gardens and similar situations may present a lower risk of PHM spread because their produce may not be commercially distributed and they may (or may not) be well tended to and treated for pests. Because they occur in diverse situations, survey techniques; regulatory actions; and control, suppressive or eradicative procedures will be decided on a case-by-case basis. Procedures will be mutually approved by cooperating State and local regulatory officials. Factors in regulatory decisions include:

- Proximity of site to areas of commercial production
- Size of garden
- Movement of hosts and pest
- Changes in size or location of garden on a property over the years
- Proximity of site to dwellings
- Suitability of the PHM to such regulatory measures

Some of these factors may also apply to the choice of survey, control, suppressive, or eradicative techniques at commercial sites.

Regulatory Options:

These include:

- Control, suppression, or eradication measures
- Prohibition of host crops at the infected site

Alternative options may be developed if deemed necessary. A quarantine or compliance agreement may or may not be required.

ADDENDUM 7

Life History

Systematic Position:

Class : Insecta
Order : Homoptera
Family: Pseudococcidae

The PHM is one of eight species in *Maconellicoccus*. The genus is probably Far Eastern, possibly of tropical Australian origins, as five of the eight species are found there. Of those five species, three have become adapted to a more moderate climate (dry subtropical), especially *M. tasmaniae*, found only in temperate Tasmania. In Southern Asia, a new species, *M. ramchensis*, has just been described from Nepal; and another species, *M. multipori*, occurs throughout the region along with *M. hirsutus*. In Africa, there are only two species including the PHM which may have spread there recently. The other species, *M. ugandae*, has a strictly tropical African distribution. (Williams, 1985; 1986; 1996)

The PHM, *M. hirsutus*, is the only *Macronellicoccus* species with a world wide distribution. It probably spread to Africa along tropical routes from the Oriental region. Some of this spread is recent, i.e., Egypt, 1908 (Williams, 1986), Hawaii, 1984 (NPAG, 1984) and the West Indies in 1994 (Pollard, 1995).

Since its discovery in Grenada in November 1994, it has been found in Trinidad in August 1995, and St. Kitts & Nevis in November 1995. It is now found in St. Lucia and St. Martin. Finally, it has been reported from host material originating in Baja, Mexico, and Guatemala, but its presence in these places has not been confirmed.

M. multipori is the only other species which appears to have the potential to be spread by commerce as it has been repeatedly intercepted on various hosts at quarantine inspection stations. It is not, however, a known pest although this status may change on its establishment in a new area. (Williams, 1996)

Biology: (From Mani, 1989 unless otherwise noted)

Males are very common but parthenogenetic reproduction has been reported in the literature. In general, reproduction is assumed to be restricted to the sexual form when the sex ratio is approximately 1:1, but both sexual and parthenogenetic reproduction has been reported under these conditions for this species.

From 84 to 654 mealybug eggs are laid in a loose cottony terminal white ovisac. They are in close touch with each other within the ovisac. Eggs turn pink before they hatch which is 3-8 days after being laid.

Newly hatched mealybugs (crawlers) are mobile. They settle on the host and start their development, which lasts 10 to 22 days. Although they show a preference for the apical and tender regions of the host, under field conditions, the older plant parts, including stems, leaves, petioles, roots, tubers and even the pods may harbor fairly large populations of the crawlers (Ghose, 1972). Male and female nymphs are distinguishable by the end of the second instar. The male has four instars of 6.60 $\pm$ 0.50 days, 6.51 $\pm$ 0.51 days, 1 day, and 5.59 $\pm$ 0.69 days each, while the females have three instars of 6.71 $\pm$ 0.47 days, 6.55 $\pm$ 0.52 days and 7.9 $\pm$ 0.79 days. At the end of the second instar, males produce a cottony cocoon (puparia). The adult male emerges after four instars and the adult female emerges after three instars respectively.

The PHM possesses a toxic saliva which may cause various symptoms in the host. These symptoms generally are severe malformation of shoots and leaves. Leaves become twisted and crinkled. Growth is stunted and shoot tips have a bushy appearance. Infested flowers dry and drop and fruits are not produced. Infested fruits are small and abnormally shaped and may drop early reducing production and marketability. (Francis-Ellis, 1995)

Specific hosts may exhibit symptoms as in the following examples:

- In Hibiscus, they usually infest young twigs causing gall-like deformations of the terminal growth. This is characterized by internode shortening (Bunchy top), deformed leaves, and thickened twigs (Veni, et al, 1973; Beardsley, 1985).

- In mulberry, the shoots of the affected plant first turn coppery green, then pale yellow, and finally become so hard, compact, and brittle that they cannot be opened without breaking. The lower lateral leaves become seared and fall off prematurely. In severe attacks, nothing but the bare stems of plants remain in the field. (Misra, 1920)

- In roselle, floral branching is suppressed, the tips are gradually withered, and the floral buds are reduced and distorted. This results in a drastic reduction in seed loss on the order of 21-43 percent of normal production due to a reduction in the number and quality of the pods (Ghose, 1972).

- In cotton, the growing parts are attacked resulting in bunchy-type symptoms. Attacked plants remain stunted and produce fewer bolls of a smaller size. Boll opening is adversely affected and yield reduction ranges from 58-73 percent (Dhawan, 1980). It is recorded but rare on the roots of cotton plants under severely attacked trees (Hosny, 1939).

- In grapevine, the mealybug feeds on the developing sprouts after pruning and stunts their growth. The growing shoots and the leaves are malformed due to sticky honeydew produced by the pest predisposing them to mouldy growth and bunching. Heavily infested bunches shrivel and drop. The extent of damage can be as much as 90 percent in some cases (Babu & Azam, 1987).

- In peanut, the mealybug feeds on the underground parts of the roots, pods, and pegs of the plant. This results in stunted growth and poorly developed pegs and pods (Rao & Srinivasan, 1987).

- In trees, the mealybug feeds on tender young growth although this can change to older growth if the infestation is high. This results in malformed leaves and shoots which become gnarled and form compact heads. As a result, dieback of young shoots and limbs may occur and result in the death of the tree. Some trees may be very obviously infested and covered with mealybugs, emitting a distinctive odor (Hall, 1921; ANON., 1996; Hall, 1926).

- In other hosts, symptoms may vary but dieback of attacked areas is often the result. Death of the host, including large trees, is very common.

The life cycle of the mealybug is completed in about a month depending on prevailing temperatures. The average developmental time for males is 24.85 $\pm$ 1.19 days and for females is 26.31 $\pm$ 1.98 days. The shortest possible developmental time per generation including preoviposition is 23 days under laboratory conditions.

After emergence from the fourth instar, adult males have a pair of wings. They remain at rest for some time when two long waxy caudal filaments about as long as the body are formed at the posterior end of the abdomen on each side of the ninth abdominal segment. When mature, one male is capable of mating with three to four females. (Ghose, 1972)

Females are wingless and dark pink to reddish in color. They tend to migrate to the lower parts of the host as the affected apical portions wither away (Ghose, 1972). Preoviposition is from 0.5 to 6 days followed by an ovipositional period of 4 to 8 days.

Oviposition normally occurs in the terminal areas of the host but when the weather gets cooler, the females search for shelter to oviposit. These include crevices in the bark (of a tree) or other shelter on the host (Hall, 1926).

Due to congregating behavior, there is a tendency for females to lay eggs in clumps on the trunk of a host. If the population is very dense, females can fall off branches and tend to congregate on a variety of substrates where they will also lay egg masses. Such substrates can include anything that provides shelter, such as firewood, outdoor furniture, etc.

Activity on roots has been reported in a few cases but the circumstances are not clear (Rao & Srinivasan, 1987; Hall, 1921; Hosny, 1939).

There are about ten generations a year in the subtropics. If there is a winter season, the PHM will hibernate or remain quiescent in any or all of its stages until food plants are again available. The pest may overwinter in protected parts of the host such as the capsules of kenaf or sorrel, cracks and crevices of bark, inside fruit bunches, or in the soil. Maximum populations are reached in late summer and early fall.

By itself, the PHM is not greatly mobile. The crawlers, ovisacs, and males may migrate by means of air currents. The females, crawlers, and nymphs are mobile and can walk from host to host over local distances. The males seem to stay within the local area as well and probably are attracted to the female over several hundred meters. (Misra, 1920- see Pathway Evaluation). This generally results in a clumped distribution of the PHM population under normal conditions. When and if the population is unrestrained, clumping tends to disappear if hosts are numerous, and as the season advances.

Predators and Parasites

Those predators and parasites known to date are listed in Control Procedures.

Entomo-pathogens

A Sporozoean, *Laterospora phenacocca*, was recently described from the PHM. (Haldar, et al, 1988)

Natural Protection

Mealy Wax:

The natural wax of the mealybug protects it somewhat against many enemies, including pesticides. This is especially true of the egg stage which is protected by the waxy ovisac. This is almost impossible to penetrate with many insecticides. (McKenzie, 1967)

Cracks & Crevices:

This is probably the most important means by which mealybugs protect themselves. Once hidden, they are difficult to reach by both natural enemies and by man. (McKenzie, 1967)

Ants:

Some sugar-loving ants will probably protect the PHM from predation. The ant, *Monomorium indicum*, was observed in India attending the nymphs and maturing females for their honeydew. They do not attend to male nymphs in the last nymphal stage nor to gravid females which have began laying eggs. (Misra, 1920)

In Papua New Guinea, control of attending fire ants, *Solenopsis* sp., significantly reduced populations of the mealybug. This result suggests that under certain conditions, ants may play a large role in protection of the PHM. (Greve & Ismay, 1983)

ADDENDUM 8

Forms Forms, as developed by the State, may be listed in this section.

ADDENDUM 9

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ADDENDUM 10

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